AD-A008 963

STUDIES ON MUST (MEDICAL UNIT, SELF-CONTAINED, TRANSPORTABLE) FIELD HOSPITAL WASTEWATER TREATMENT

John G. Vlahakis

Army Mobility Equipment Research and Development Center
Fort Belvoir, Virginia

December 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

Destroy this report when no longer needed. Do not return it to the originator.

The citation in this report of trade names of commercially available products does not constitute official endorsement or approval of the use of such products.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 2121 — 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER AD-A008 963
4. TITLE (and Subtitle) STUDIES ON MUST FIELD HOSPITAL WASTEWATER TREATMENT	5. TYPE OF REPORT & PERIOD COVERED Final Technical Report September 1973 – June 1974
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John G. Vlahakis, Ph. D.	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Sanitary Sciences Division, U.S. Army Mobility Equipment Research and Development Center Fort Belvoir, Virginia 22060	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1G762708AH67
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Mobility Equipment Research and Development Center Fort Belvoir, Virginia 22060	12. REPORT DATE December 1974
	13. NUMBER OF PAGES 61
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Wastewater treatment
Coagulation
Reverse osmosis
Powdered carbon

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report investigates the applicability of using polyelectrolyte-aided-carbon coagulation as a pretreatment in combination with a high-recovery reverse osmosis (RO) system to treat a synthetically prepared Medical Unit, Self-Contained, Transportable (MUST) hospital wastewater with variable characteristics.

The five-source hospital waste consisted of X-ray, operating room, laboratory, shower, and kitchen waters.

(Continued)

(Block 20 Cont'd)

A 10,000-gpd pilot plant was tested on a 200-hour basis, 100 consecutive hours per run. The system involved polyelectrolyte-aided-carbon coagulation, upflow clarification, diatomaceous earth filtration, and demineralization by spiral-wound RO. The MUST wastewater was adequately treated by this process.

SUMMARY

The purpose of the work was to determine the applicability of using polyelectrolyte-aided-carbon coagulation, upflow, solids-contact, clarification, and pressure diatomite filtration as a pretreatment for a high-recovery, reverse osmosis (RO) system to treat a synthetically prepared Medical Unit, Self-Contained, Transportable (MUST) hospital wastewater of time-varying composition. The ultimate goal was direct recycle and reuse of the water for all except potable purposes.

The hospital wastewater totalling 63 ingredients consisted of five components: X-ray, operating room, laboratory, shower, and kitchen.

Preliminary chemical pretreatment laboratory studies of composite and specific wastewaters were accomplished by jar test analysis. Two powdered carbons and four different cationic and anionic polymers were tested. Turbidity reductions of the treated waters were excellent, reaching as high as 97%. Total organic carbon (TOC) removals averaged about 50% in these jar test experiments.

Based on these results, a 10,000-gpd pilot plant was tested on a 200-hour basis, 100 consecutive hours per run, to determine its performance by evaluating the following parameters: TOC; turbidity; pH; chemical oxygen demand (COD); linear alkyl sulfonates (LAS); total hardness; total alkalinity; suspended solids; conductivity; silver, chromium, zinc; and RO flux and salt rejection. The principles of the system involve polyelectrolyte-aided-carbon coagulation, upflow clarification, diatomaceous earth filtration, and demineralization by spiral-wound RO. Each component wastewater was pumped into an equalization feed tank at programmed times and flow rates before treatment, resulting in a composite feedwater of time-dependent quality. Composite COD varied from 165 to 1028 mg/l; TOC, from 51 to 195 mg/l, and turbidity, from 5 to 55 JTU. Water-quality parameters varied in a regular, predictable manner within a period of 24 hours.

A comparison of chemical pretreatment performance versus RO performance was made. During peak TOC and COD loading periods, the coagulation step accounted for a 30% reduction in feedwater TOC while the RO unit reduced TOC an additional 44%. At the minima of TOC versus operating time, many low-molecular-weight compounds can bleed through the cellulose acetate membrane and RO performance diminishes. In this case, adsorption-coagulation-filtration removes 60% of the averaged TOC while the high-recovery RO unit removes an additional 15% of TOC on the same basis. COD and TOC are shown to correlate strongly on a linear basis, and relationships are calculated separately for feed, filtrate, and RO permeate. The ratio of COD/TOC, indicative of the amount of oxidizable material making up the total organic matter, is presented for

the wastewater as it progresses through the system. On the average, the ratio decreases from 3.8 in the feed to 2.7 after coagulation-filtration, to 1.5 after RO.

The spiral-wound, high-recovery RO system was operated at an average recovery rate of 91.5% with an average feed total dissolved solids (TDS) of 893 mg/l. Salt rejection properties of the cellulose acetate membrane showed little deterioration over the life of the test, varying mostly between 84% and 94%. Flux normally varied from 9.5 to 16 gf^2d.

Brief experiments using $KMnO_4$ and ozone showed that chemical oxidation could destroy most of the refractory compounds in the RO permeate.

This report concludes that:

a. The system comprising polyelectrolyte-aided-carbon coagulation, upflow, solids-contact clarification, and pressure diatomite filtration is an acceptable pretreatment for a high-recovery reverse osmosis unit in treating MUST field hospital wastewater. Sparkleen acts as an anti-coagulant, however, and must be omitted from the kitchen wastewater.

b. Dosages of 1000 mg/l Nuchar A and 100 mg/l Cat-Floc successfully treated MUST wastewater in the pilot plant unit.

c. A reverse osmosis unit equipped with spiral-wound membrane modules recovered greater than 90% of the pretreated feedwater.

d. The Wastewater Reclamation Unit combined with the RO unit can achieve reductions in average turbidity from approximately 30 JTU to 0.3 JTU, average TOC from over 100 mg/l to 25 mg/l, and average COD from 445 mg/l to about 50.

PREFACE

This work was partially funded by the U. S. Army Medical Research and Development Command, Washington, D. C., under Intra-Army Order 4720, dated 10 September 1973. Work was accomplished under the general direction of Richard P. Schmitt, Chief, Sanitary Sciences Division, USAMERDC and Lt Colonel Leroy H. Reuter, Medical Research and Development Command, Office of the Surgeon General.

Analytical work for the MUST waters was performed by Robert Ross, chemist, and staff, and the field testing was a cooperative effort of the Sanitary Sciences Division.

CONTENTS

ILLUSTRATIONS

TABLES

STUDIES ON MUST FIELD HOSPITAL WASTEWATER TREATMENT

I. INTRODUCTION

1. **Background.** There is a need to obtain data relative to treating Medical Unit, Self-Contained, Transportable (MUST) field hospital wastewaters with the ultimate goal of direct recycle and reuse for all except potable purposes. A recycle system has the advantages of not only providing for improved pollution abatement but enhanced operational flexibility both in the field and at fixed installations. A previous study indicated that further work was necessary to properly treat MUST waters.[1]

This study was jointly funded by the U.S. Army Medical Research and Development Command and the U.S. Army Mobility Equipment Research and Development Center (MERDC). The purpose of the work was to determine if a polyelectrolyte-aided-carbon coagulation scheme coupled with a modified standard Army Water Purification Unit and a high-recovery, reverse osmosis system could be utilized to effectively treat a hospital-type wastewater of time-varying composition.

More specifically, both laboratory studies and field work have been carried out in response to a two-fold objective: (1) to determine optimum pretreatment of varying composition MUST hospital wastewaters for subsequent application to a reverse osmosis (RO) system, and (2) evaluation of a 420 gallon per hour (gph), spiral-wound RO unit for recovering up to 90% of the pretreated wastewater volume.

The program consisted of the following phases:

a. Preliminary chemical pretreatment laboratory studies of composite and specific synthetic MUST hospital wastewaters by jar test analysis. Powdered, activated carbon and cationic and anionic polymers were used to evaluate the coagulation process. Total organic carbon (TOC) and turbidity of raw and treated water were the main parameters used to judge the effectiveness of the differing doses of carbon and polymer.

b. Test and evaluation of the optimum treatment (based on the laboratory study) utilizing a 420-gph clarification unit on synthetically prepared, composite MUST hospital wastewater.

c. Filtration tests of the effluent from the 420-gph clarification unit using diatomite filtration. Criteria for evaluation of filter performance were clarity of effluent

---

[1] A. Gouveia, and K.A.H. Hooton, "Potable Water from Hospital Wastes by Reverse Osmosis," C.E.P. Symposium Series, *64*, No. 90, pp. 280-284, 1968.

and filtrability of water determined by measuring quantity of water filtered per unit of pressure differential.

d. Test and evaluation of spiral-wound RO modules for demineralizing composite MUST wastewater which has been pretreated by clarification with subsequent filtration. The 420-gph clarification unit was employed to integrate the RO unit into a total system. The spiral-wound RO unit was fabricated to provide up to 90% recovery.

The five component waters were X-ray, laboratory, kitchen, operating room, and shower. The chemical makeup of the MUST wastewater appears in Appendix A.

II. LABORATORY INVESTIGATION

2. **Adsorption-Coagulation Jar Tests.** Laboratory jar testing of specific and composite MUST wastewater samples was undertaken to help evaluate the applicability of using the carbon-polymer process for wastewater treatment. Varying dosages of carbon and polyelectrolyte in jar tests can furnish only general information for scale-up purposes due to differing fluid dynamics involved. This series of tests was carried out with the specific goal of determining which types of carbon and polymer should be further investigated, the nature of the resulting floc, and effective dosage ranges. By considering the relationship between the configuration of the Wastewater Reclamation Unit (WWRU) and the simple jar test setup, one could estimate potentially effective carbon-polymer concentrations for field testing from laboratory work. It was also hoped that any serious barriers to the viability of this coagulation process could be isolated and overcome in the laboratory.

TOC and turbidity removals were used as criteria of effectiveness for this process. Initially, each synthetic component wastewater was treated separately. This was done to pinpoint potential problems associated with any specific substance or group of substances contributing to the composite water.

Also, since the MUST water composition is a function of time, composite samples were prepared by selecting a specific instance of time on the mass diagram schedule and mixing the component waters in the appropriate proportions. The resulting mixture was designated by "composite" followed by the appropriate time index in minutes. Individual jar test results are tabulated in Appendix B.

For each adsorption-coagulation jar test, 500 ml of synthetic MUST water was placed in a 1000-ml beaker and mixed with a Phipps and Bird gang stirrer at low speed. Hydrodarco C or Nuchar A powdered, activated carbon was added to the beakers. As the stirrer speed was increased to about 90 rpm, the polymer was added. The stirrer speed was held at 90 rpm for a 1-minute mix time and then decreased to 30 rpm for a

flocculation time of 60 minutes. The flocculated samples were allowed to settle for 15 minutes. About 30 ml of the supernatant was then pipetted from near the middle of the beaker, approximately one-half inch below the surface of the liquid, for analysis.

In some cases, a second coagulant was added to the beakers midway through the flocculation period to improve turbidity or floc appearance. This occasionally led to marginally better results than cited in Table 1 but was not stressed due to the introduction of complexities for field application.

The general results of nearly 300 jar tests are summarized in Table 1. (Kitchen wastewater treatment will be discussed more fully later.) Of the organic coagulants tested—Cat-Floc, Atlasep 1A1, 2A2, and 105C—Cat-Floc was found to be the single most effective polyelectrolyte and Nuchar A the better powdered, activated carbon based on TOC and turbidity removals. The candidate chemicals were chosen from previous experience in treating other wastewaters.

As shown in Table 1, the optimum dosage of Nuchar A is 2000 mg/l for the four treated specific wastewaters as well as for composite 1440. For X-ray, operating room, shower, and composite 1440, optimum Cat-Floc dosages ranging from 1 to 50 mg/l were established. Due to the low pH of the laboratory waste, 0.5 mg/l of the moderately cationic Atlasep 105C was optimum.

Turbidity reductions of the treated waters were excellent, ranging from 80% for operating room wastewater to 97% for shower and X-ray waters. TOC reductions ranged from 16% for X-ray to 63% for composite 1440. Although the TOC reduction for X-ray water was poor, this component waste represents only 3.3% by volume of the overall composite water.

Table 2 shows the characteristics of the component waters and the overall composite 1440. Table 3 gives the range of dosages utilized in the jar tests for each chemical, while Table 4 presents some general properties of the powdered, activated carbons. Selection of polymer types and dosages shown in Table 3 could be correlated generally with the pH of the water.

It was apparent from this phase of the jar testing that the kitchen wastewater should be more thoroughly investigated and also that other composite samples should be examined due to their widely varying characteristics as a function of time. In addition, there was evidence of difficulty in coagulating freshly prepared composites containing kitchen waste in almost any proportions. First, simple artificial composites were prepared without kitchen or operating room wastes. Upon successful treatment, a 4-part composite was made without kitchen water. Then, increasing dosages of kitchen water were added to the 5-part formula for the composite 1440 until treatment

Table 1. MUST Wastewater Jar Test Summary

Wastewater Type	TOC Raw (mg/l)	TOC Treated (mg/l)	% Reduction	Turbidity Raw (JTU)	Turbidity Treated (JTU)	% Reduction	Optimum Carbon Type and Dosage	Optimum Single-Polymer Type and Dosage	Percent of Total Volume Composite 1440
Composite 1440	204	75	63	36	6.3	83	2000 mg/l Nuchar	5 mg/l Cat-Floc	100.0
Shower	112	50.5	55	75	2.6	97	2000 mg/l Nuchar	15 mg/l Cat-Floc	50.5
Operating Room	106	52	51	4.5	0.9	80	2000 mg/l Nuchar	50 mg/l Cat-Floc	26.2
Kitchen	611	*	–	120	*	–	–	–	11.7
Lab	246	147	40.2	18	1.5	92	2000 mg/l Nuchar	0.5 mg/l Atlasep 105C	8.3
X-Ray	1397	1172	16	61	1.7	97	2000 mg/l Nuchar	1 mg/l Cat-Floc	3.3

* Untreated.

Table 2. MUST Wastewater Characteristics

	Composite 1440	Laboratory	Operating Room	X-Ray	Shower	Kitchen
Turbidity, JTU	37	18	2.9	83	75	120
pH	7.0	2.0	9.8	7.6	7.0	9.3
Conductivity, micromhos/cm	1625	9100	1600	8000	320	2600
Linear Alkylate Sulfonate	95	12.0	42.0	7.6	0.6	500
Total Hardness ($CaCO_3$)	84	72	40	688	62	62
Total Alkalinity ($CaCO_3$)	118	4	392	1144	6	530
Total Carbon	212	273	148	1425	117	690
Inorganic Carbon	8	27	42	28	6	79
Total Organic Carbon	204	246	106	1397	111	611
COD	746	499	301	6563	380	2780
Suspended Solids	66	11	2	76	125	514

NOTE: Units in mg/l unless noted otherwise.

Table 3. Range of Dosages Used in MUST Wastewater Jar Testing

			Atlasep*		
Wastewater Type	Carbon	Cat-Floc*	105C	1A1	2A2
Composite	1000-3000	1-250	–	2-5	–
Shower	500-2000	1-50	1-50	2	–
Operating Room	50-2000	1-175	–	1-150	–
Kitchen	500-4000	1-400	25	25-40	–
Lab	1000-2000	0.25-1.0	0.05-100	0.25-1.0	0.25
X-Ray	1000-2000	1-150	1-10	2	–

NOTE: All values in mg/l.

*Polymer	Ionic Character
Cat-Floc	Cationic Charge
Atlasep 105C	Moderate Cationic Charge
Atlasep 1A1	Weak Anionic Charge
Atlasep 2A2	Weak-Moderate Anionic Charge

Table 4. Properties of Powdered Carbons

Origin	Hydrodarco C Lignite	Nuchar A Wood
Particle Size,		
%-100 Mesh	—	99
%-300 Mesh	65	90
Apparent Density, lb/ft^3	30.8	15.2
Surface Area, m^2/g	550	754
Molasses Value	95	80
Wettability	Superior	Good

was accomplished.

In order to establish the constituent in the kitchen water which was chiefly responsible for the anti-coagulation action, samples of this wastewater with varying amounts of detergent and Sparkleen were tested. Only samples without Sparkleen could be treated. Kitchen waste with only 25% of the required dosage of Sparkleen could not be effectively coagulated.

Further work with selected time composites indicated that 2000 mg/l Nuchar A and from 25 to 100 mg/l Cat-Floc were optimum. Four exemplary time composites were used: 480, 800, 1200, and 1440 minutes from system start-up. The samples were prepared without Sparkleen. Turbidities were reduced by about 80% and TOC, by nearly 50%. When Sparkleen was added to the 800-minute composite, the Cat-Floc dosage had to be increased from 25 mg/l to 100 mg/l to attain comparable treatment. Since the 800-minute composite contained only 19% kitchen water, this showed a very sensitive dependence of polymer dosage on Sparkleen content.

Results of the jar testing indicated that Nuchar A was the superior carbon based on turbidity and TOC removal. The only foreseeable difficulty in using this carbon was its comparatively inferior wettability. Cat-Floc polymer was chosen as the more generally applicable coagulant for the MUST water. Two possible operational problems in scale-up included the relatively inferior wettability of the Nuchar A and extreme coagulant sensitivity to Sparkleen dosage.

III. SYSTEM OPERATION

3. **Description.** The principles of the system involve polyelectrolyte-aided-carbon coagulation, upflow, solids-contact clarification, diatomaceous earth filtration,

and demineralization by reverse osmosis. Details of the WWRU are shown in Figures 1 and 2. The field set-up is depicted in Figure 3.

The five-source hospital wastewater is pumped into the equalization tank and then enters the WWRU 500-gallon mixing tank. At this point, a carbon slurry is fed to the continuously stirred wastewater while cationic polyelectrolyte is metered through a solution feeder. The contents of the mix tank have approximately a 1-hour residence time. This mixture is pumped from the mixing tank to the upflow solids-contact clarifier. Effluent from the clarifier is collected in a clear well and is then pumped through a distomaceous earth pressure filter. The sludge from the clarifier is collected in a sludge concentrator for subsequent reuse or disposal. The filtrate is demineralized by a spiral-wound reverse osmosis system operating at approximately 90% recovery. The feed to the reverse osmosis unit is chlorinated and pH is adjusted to a range of 5 to 7 to preserve membrane life. The reverse osmosis unit, fabricated by Gulf Environmental Systems, Inc., contains 711 sq ft of membrane area. The unit is made up of six 4-in. diameter elements of 65 sq ft each, six 3-in. diameter elements of 33 sq ft each, and nine 2-in. diameter elements of 17 sq ft each for optimum fluid dynamics necessary in a high recovery system.

4. **Procedure.** It is sometimes confusing to speak of a MUST wastewater composite since the discharge of each specific component water into the composite (or equalization) tank is time dependent. Because the composite is time-variant over a 24-hour period, and reproducible results were sought, a synthetic waste of specified composition was produced. A series of timers controlled the imput to the equalization tank to simulate the functioning of an actual field hospital. Composition, pumping, and flow rates were based on data presented in the USAEHA-ES Special Study No. 99-003-71 (MUST).[2] Scale-up was necessary in order to accommodate the existing 420-gph WWRU available at the Sanitary Sciences Division, MERDC. The 1200-gpd treatment unit required for a 60-bed field hospital was expanded to a flow rate of 10,080 gpd.

Each source tank was refilled daily by preparing the waste concentrate in the laboratory, adding the concentrate to the tank, and feeding tap water from a high-pressure hose up to the appropriate level on a calibrated rod attached to the tank wall. A recirculating pump was installed in each tank to provide constant agitation.

The pumping schedule and flow rates are delineated below:

Operating Room: 30 discharges of 15 minutes each, spaced over 24 hours at 355 gph.

---

[2] Water Quality Engineering Special Study No. 99-003-71, U.S. Army Environmental Hygiene Agency, Edgewood Arsenal, Md., 1971.

Laboratory: Discharge of 120 gph from 0900 to 1600 hours.

X-Ray: Discharge of 42 gph from 0900 to 1700 hours.

Kitchen: Flow rate of 168 gph during the following times: 0800 to 1000, 1200 to 1400, 1700 to 1900, and 2300 to 2400 hours.

Shower: Flow rate of 1000 gph at 0500 to 0730, 1600 to 1900, and 2315 to 2400 hours.

The mass diagram appears in Figure 4. Cumulative volumes for each constituent are as follows:

Constituent		Daily Volume (gallons)
Operating Room		2640
Kitchen		1176
Laboratory		840
X-Ray		336
Shower		5080
	TOTAL	10,080

The field system was tested on a 200-hour basis, 100 consecutive hours per run, to determine its performance by evaluating the following parameters: TOC; turbidity; pH; COD; LAS; total hardness; total alkalinity; suspended solids; conductivity; silver, chromium, zinc; and RO flux and salt rejection. Soluble metals were determined by FWPCA Methods,[3] while other routine analyses were conducted as described in Standard Methods.[4]

Grab samples were collected for analysis at specified times from the five component source tanks as well as from the equalization tank, the filtrate tank, and the RO product tank.

A computer model of the flow scheme into and out of the equalization tank has been formulated in order to size the tank properly. The detailed report concerning this model will be given at a later date, but the conclusions include the recommendation of a 3000-gallon equalization tank.

[3] "FWPCA Methods for Chemical Analysis of Water and Wastes," U.S. Dept. of Interior, FWPCA Division of Water Quality Research, Cincinnati, Ohio, Nov. 1969.

[4] "Standard Methods for the Examination of Water and Wastewater," 13th Ed., American Public Health Assoc., Inc., 1971.

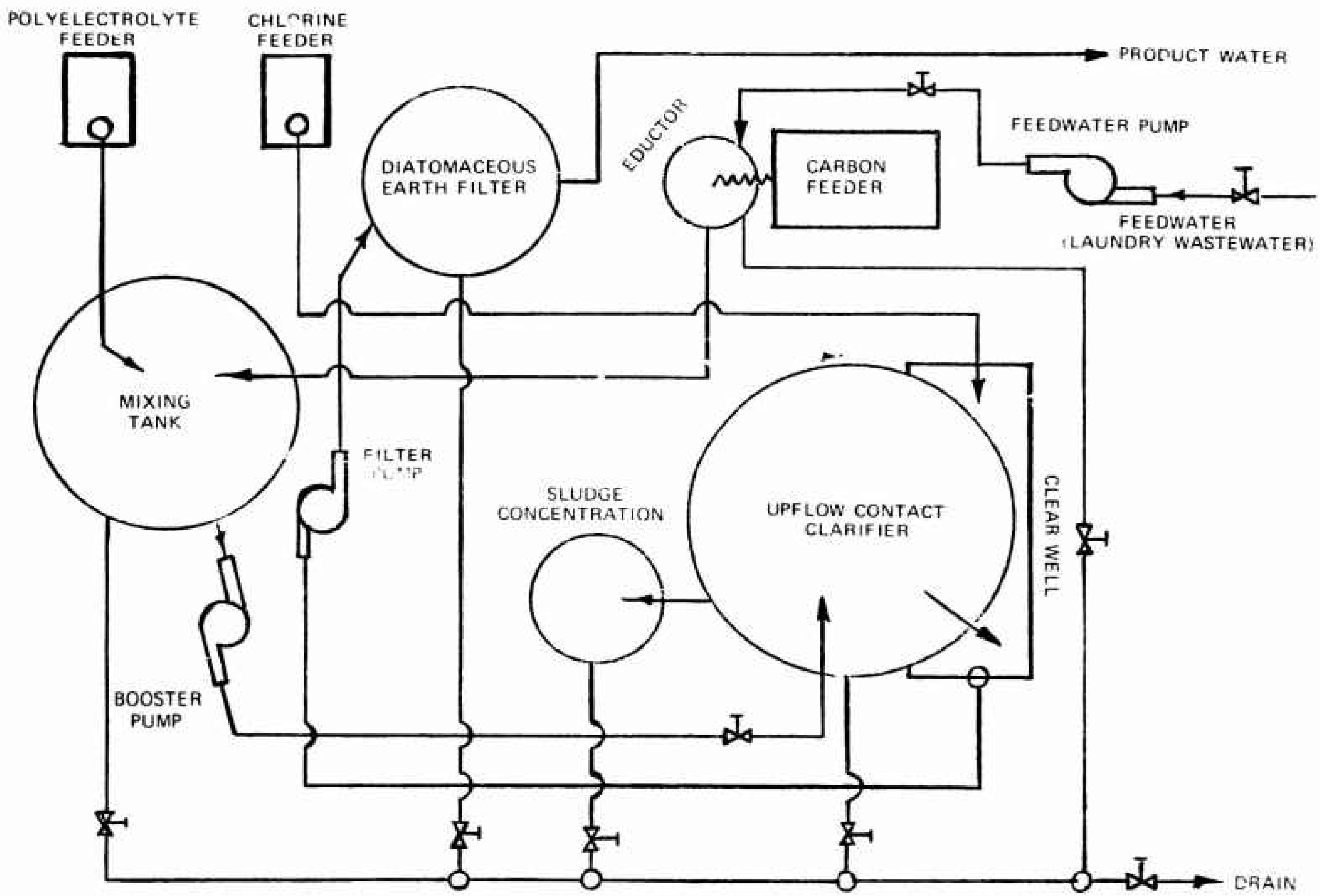

Figure 1. Flow Diagram of MUST Wastewater Reclamation Unit.

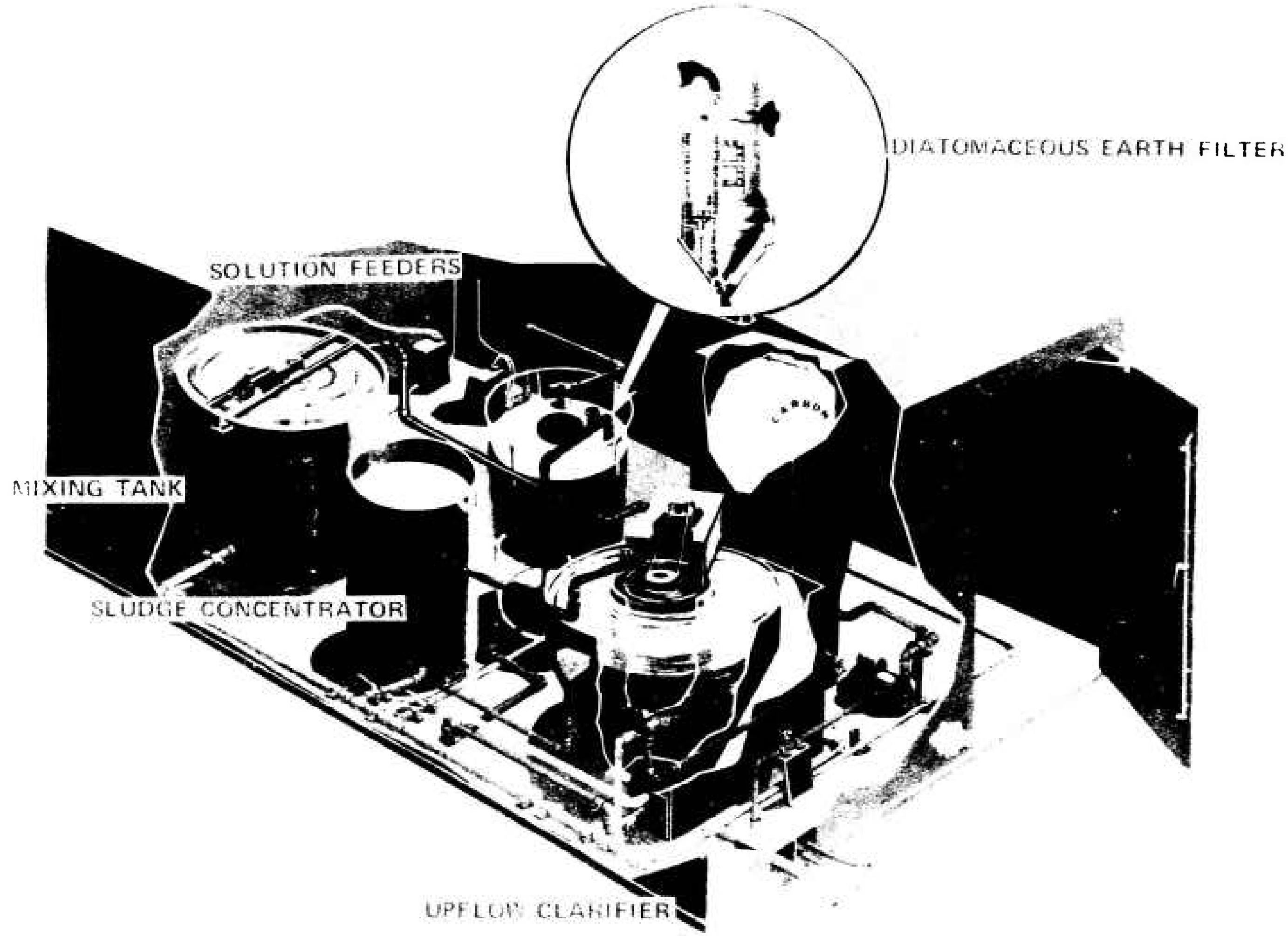

Figure 2. Wastewater Reclamation Unit.

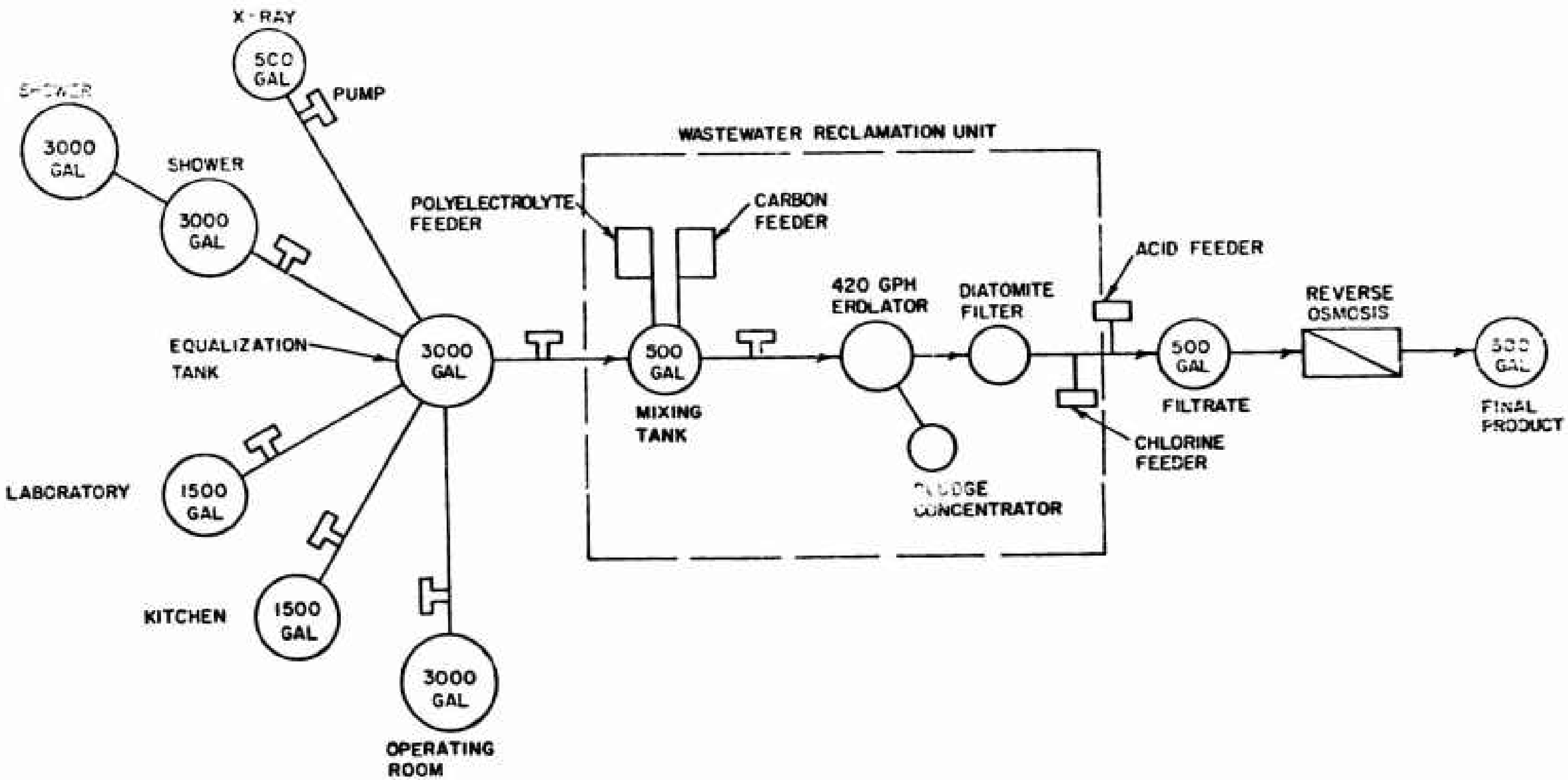

Figure 3. Flow diagram of wastewater reclamation system MUST study.

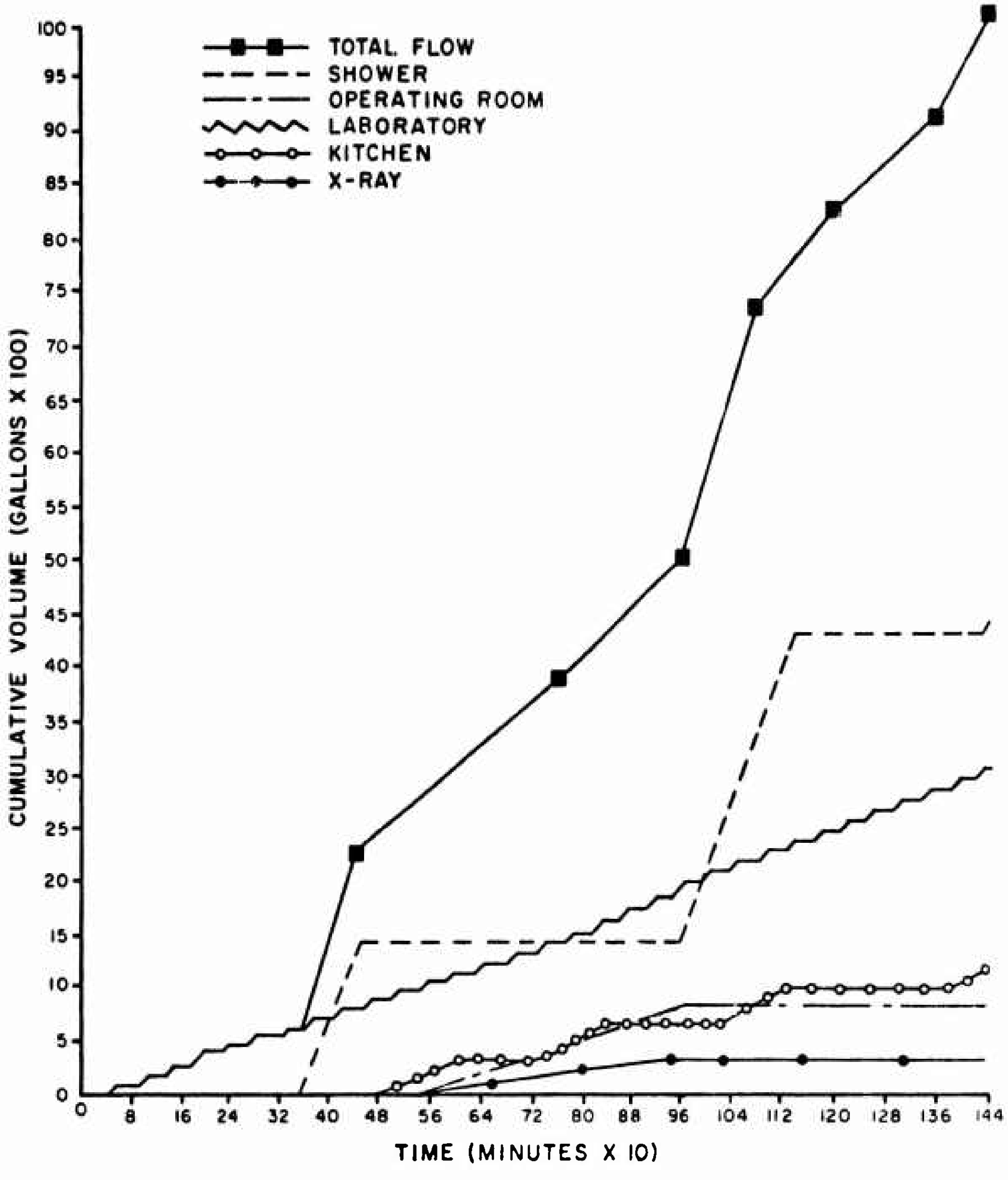

Figure 4. Mass diagram of five-source hospital wastewater.

5. **Results.**

a. **General.** Polymer and carbon dosages were generally fixed before the field tests were begun. The laboratory jar testing established that the field test dosages required would probably be in the ranges of 600 to 1000 mg/l Nuchar A and 50 to 100 mg/l Cat-Floc. Approximately 1000 mg/l Nuchar A and 100 mg/l Cat-Floc were used in the WWRU during most of the operating time to adjust for continuous-flow operation. Jar testing had also indicated that two operational problem areas would be carbon wettability and the anticoagulation properties of Sparkleen. Both of these problems did, in fact, occur. The screw-type dry carbon feeder installed in the unit was replaced with a slurry feeder after clogging difficulties were experienced on the second day. Also, during the first week of runs, Sparkleen in the kitchen water caused the WWRU to malfunction, thus causing extremely short filter runs (Table 5). When the Sparkleen was eliminated from the kitchen wastewater, the system performed extremely well (Table 5, day 3). Even 25% of the recommended dosage of Sparkleen prevented effective coagulation (Table 6, day 6). Filter runs as long as 14 hours and 20 minutes were noted without Sparkleen. Several other runs were terminated prematurely because the sludge concentrator had not been properly drained on day 9. All filter runs for both weeks averaged approximately 73 gallons of effluent per psi of filter pressure, or over 3600 gallons of treated water before backwashing at 50 psi. This is shown in Table 7.

During the second week of operation, careful attention was paid to a breakdown of treated wastewater filter effluent versus unrecovered waste streams. During this week, total filter effluent amounted to 36,398 gallons or 91.6% of the wastewater influent. Of the remaining 3343 gallons of waste, 2089 gallons or 62.5% were by-passed during filter backwash and could easily have been recycled to the equalization tank; and 1254 gallons of waste (3% of the total wastewater influent) were accounted for in the sludge concentrator waste and filter blowdown. A large proportion of this waste could be recycled into the WWRU mix tank, thereby recovering more water and also more effectively utilizing the carbon. Although recycle was not employed, this concept represents an area for future investigation.

Tables 8 through 11 summarize the system wastewater characteristics. Tables 8 and 9 show the degree of treatment achieved each week of the field test while Tables 10 and 11 illustrate the same parameters for the contributory wastewaters.

b. **Evaluation of Parameters: TOC and COD.** Figures 5, 6, 7, and 8 clearly show the TOC and COD removals under the dynamic loading of the five-source MUST water. During the peak TOC and COD loading periods, the adsorption-coagulation-filtration steps remove a sizable percentage of the contaminants on the average, but further treatment is obviously required. WWRU effluent contains about 96 mg/l TOC averaged over five peaks versus 140 mg/l TOC in the feed at these maxima. This is

Table 5. Daily Operating Data: 15 Apr – 19 Apr
(100-Hour Continuous Test)

Day	Dosages		Wastewater Influent		Filter Effluent		Filter Cycle	
	Carbon (mg/l)	Polymer (mg/l)	(total gallons)	(gph)	(total gallons)	(gph)	Duration (hr:min)	Terminal Pressure (psi)
[illegible]	817	77.5					0:40	50
2	703	92	8525	355			0:35	52
							3:52	52
							3:00	50
3	990	97	9715	405	7930	330	1:50	50
							0:40	50
							0:35	50
							10:27	52
							12:08	49
4	940	102	9855	411	7720	320	5:05	50
							0:55	56
							0:15	50
							0:23	50
							1:20	48
[illegible]	950	110	4960	413	4690	391	13:35	50
							5:20	15

Table 6. Daily Operating Data: 29 Apr – 3 May
(100-Hour Continuous Run)

Day	Dosages		Wastewater Influent		Filter Effluent		Total Waste (gallons)	Sludge Concentrator Waste (gallons)	Filter Blowdown (gallons)	Recoverable Wastewater (gallons)	Filter Cycle		
	Carbon (mg/l)	Polymer (mg/l)	(total gallons)	(gph)	(total gallons)	(gph)					No.	Duration (hr:min)	Terminal Pressure (psi)
6	990	110	1377	365	3593	299	784	66	66	652	1	0:45	50
											2	0:50	50
											3	12:00	50
7	1055	103	9789	408	9010	376	770	198	99	473	1	3:30	50
											2	7:12	52
											3	14:20	50
8	975	110	10175	424	9726	405	419	165	66	218	1	7:55	52
											2	11:54	50
9	935	107	9700	404	9030	376	670	264	99	307	1	8:30	50
											2	8:32	42
											3	5:07	50
10	910	108	5700	438	5030	387	670	165	66	439	1	8:25	50
											2	2:25	10
TOTALS			39741		36398		3343	858	396	2089	13	91:25	

Table 7. MUST Wastewater Treatment: Daily Operating Filter Data

Day	Filter Effluent (gph)	Filter Cycle (hr:min)	Pressure (psi)	Total Gallons (gph x time)	Gallons (per psi)
Run 1					
3	330	1:50	50	660	12.08
		0:40	50	220	4.4
		0:35	50	192	3.85
		10:27	52	3465	66.63
	326	12:08	49	3912	79.83
4	322	5:05	50	1610	32.2
		0:55	56	322	5.75
		0:15	50	80	1.61
		0:23	50	123	2.47
	356	1:20	49	473	9.66
5	391	13:35	50	5278	104.40
		5:20	15	2084	138.93
				Average: 76 gal/psi	
Run 2					
6	299	0:45	50	224	4.48
		0:50	50	249	4.98
		12:00	50	3588	71.76
7	376	3:30	50	1316	26.32
		7:12	52	2707	52.06
		14:20	50	5388	107.76
8	405	7:55	52	3240	62.31
		11:54	50	4860	97.2
9	376	8:30	50	3196	63.92
		8:32	42	3196	76.09
		5:07	50	1880	37.6
10	387	8:25	50	1354	65.79
		2:25	10	967	96.75
				Average: 70 gal/psi	

Table 8. Summary of Wastewater Characteristics
(15 Apr – 19 Apr)

Characteristics	Equalization Tank		Product Tank		RO Product Tank	
	Average	Range	Average	Range	Average	Range
Turbidity, JTU	25.6	.5-55	1.5	.2-4.8	.2	.07-.6
pH	8.9	8.2-9.5	8.3	4.2-9.2	5.3	2.9-8.7
LAS	39	6-108	1.74	1-40	–	–
Total Hardness	71.3	44-120	60.2	32-122	56	56
Total Alkalinity	336	50-520	289	178-420	–	–
COD	422	206-1028	173	44-326	55	32-92
TOC	95.8	51-180	54	17-112	25	9-47
Suspended Solids	39	1-61	9.6	0-29	–	–
Conductivity, micromhos/cm	1022	480-2200	940	96-1390	274	64-1050
Silver	.533	.01-2.18	.24	0-1.15	.004	0-.07
Chromium	.09	.03-.32	.08	.03-.17	.02	.01-.03
Zinc	.189	.045-.756	.126	.028-.945	.056	.009-.129

NOTE: All units mg/l except as noted.

Table 9. Summary of Wastewater Characteristics
(29 Apr – 3 May)

Characteristics	Equalization Tank		Product Tank		RO Product Tank	
	Average	Range	Average	Range	Average	Range
Turbidity, JTU	33	13-55	1.8	.87-3.2	.42	.07-1.9
pH	8.6	7.1-9.3	8.4	3.7-9.1	6.3	3.7-8.0
LAS	178	12-2460	.5	.1-3.0	–	–
Total Hardness	58	46-76	46	24-56	–	–
Total Alkalinity	322	115-530	290	135-480	–	–
COD	467	165-988	179	39-391	47	15-291
TOC	119	66-195	57	24-110	25	14-45
Suspended Solids	48	30-108	11	1-28		
Conductivity, micromhos/cm	992	410-2700	852	550-1330	148	78-310
Silver	.006	0-.06	.004	0-.03	0	0
Chromium	.10	.01-.24	.06	0-.17	.02	0-.05
Zinc	.07	.018-.430	.224	.044-.546	.02	0-.081

NOTE: All units mg/l except as noted.

Table 10. Summary of Component Wastewater Characteristics
(Week 1)

Characteristics	Shower Average	Shower Range	Operating Room Average	Operating Room Range	Kitchen Average	Kitchen Range	X-Ray Average	X-Ray Range	Laboratory Average	Laboratory Range
Turbidity, JTU	34	18-60	2.2	.6-5.0	57	23-97	24	2.3-34	4.5	4.0-4.9
pH	7.5	6.7-8.1	9.6	8.8-10.0	9.8	9.7-9.8	7.4	7.2-7.5	7.8	7.5-8.2
LAS	1.08	.84-1.2	129	21-450	256	21-540	9.44	1.2-20	14	14
Total Hardness	84	66-102	55	6-86	40	12-66	231	74-474	72	58-94
Total Alkalinity	62	30-110	317	70-540	1488	1101-1600	982	780-1260	140	100-170
COD	138	89-240	271	24-440	562	149-980	5598	5400-6200	468	429-524
TOC	43	32-73	81	14-136	190	70-310	1296	1220-1420	137	130-152
Suspended Solids	69	58-98	6.8	1-11	220	64-322	43	24-65	24	11-36
Conductivity, micromhos/cm	381	270-520	1218	180-2160	2488	1500-3340	8016	6800-10800	343	310-380
Silver	0	0	0	0	.004	0-.02	1.64	.64-3.32	.02	0-.03
Chromium	.024	.002-.003	.026	.02-.04	.036	.02-.05	.042	.01-.07	.95	.86-1.09
Zinc	.135	0-.359	.272	.036-.922	.187	.033-.414	.38	.109-.776	.781	.480-.973

NOTE: All units mg/l except as noted.

Table 11. Summary of Component Wastewater Characteristics
(Week 2)

Characteristics	Shower Average	Shower Range	Operating Room Average	Operating Room Range	Kitchen Average	Kitchen Range	X-Ray Average	X-Ray Range	Laboratory Average	Laboratory Range
Turbidity, JTU	51	38-63	3.0	1.5-6.0	84.5	44-145	49	9-75	5.3	4.5-6.5
pH	6.8	6.4-7.3	9.6	9.5-9.7	9.7	9.7-9.8	7.7	6.6-8.6	7.7	7.1-8.2
LAS	1.2	1.2	36.7	27-48	210	90-540	5.4	3-9	12.7	12-14
Total Hardness	64	60-67	35	28-51	45	38-54	65	36-90	59	52-62
Total Alkalinity	39	35-40	310	250-365	1160	1145-1210	752	210-1140	135	130-140
COD	207	178-275	305	209-373	489	340-606	5162	3645-6402	414	297-585
TOC	63	53-75	94	82-110	182	160-210	1274	1020-1600	110	102-120
Suspended Solids	68	38-95	6	1-13	250	194-303	294	52-868	23	5-51
Conductivity, micromhos/cm	451	230-1060	1197	900-1900	1881	1550-2700	6990	2350-12000	345	300-470
Silver	0	0	0	0	0	0	.25	.04-.75	0	0
Chromium	.02	.01-.03	.02	0-.03	.02	.01-.03	.02	.01-.03	.63	.02-.83
Zinc	.009	.001-.024	.105	.002-.337	.081	.021-.185	.111	.079-.178	.197	.044-.577

NOTE: All units mg/l except as noted.

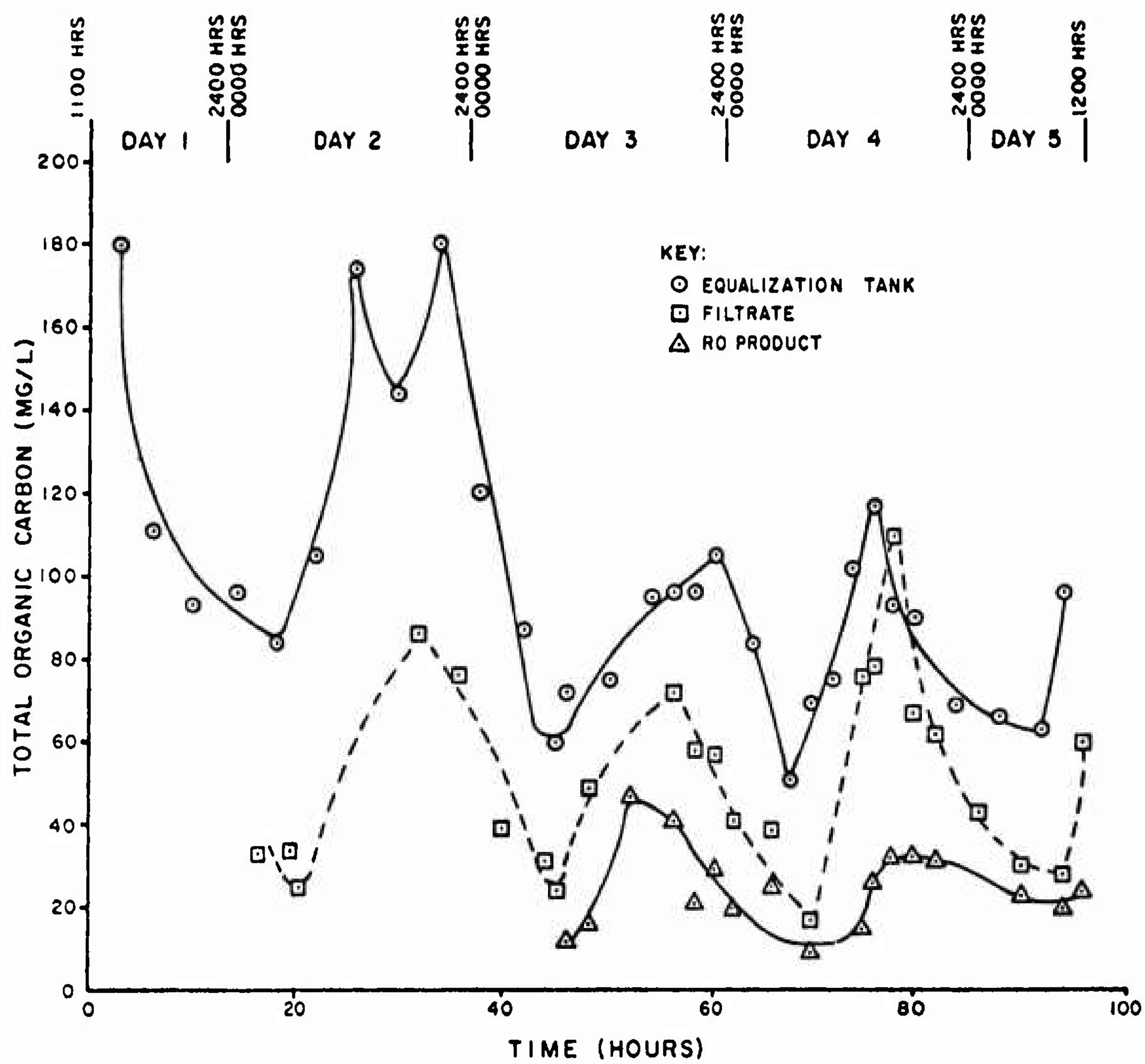

Figure 5. MUST field hospital wastewater treatment: total organic carbon versus time (week 1).

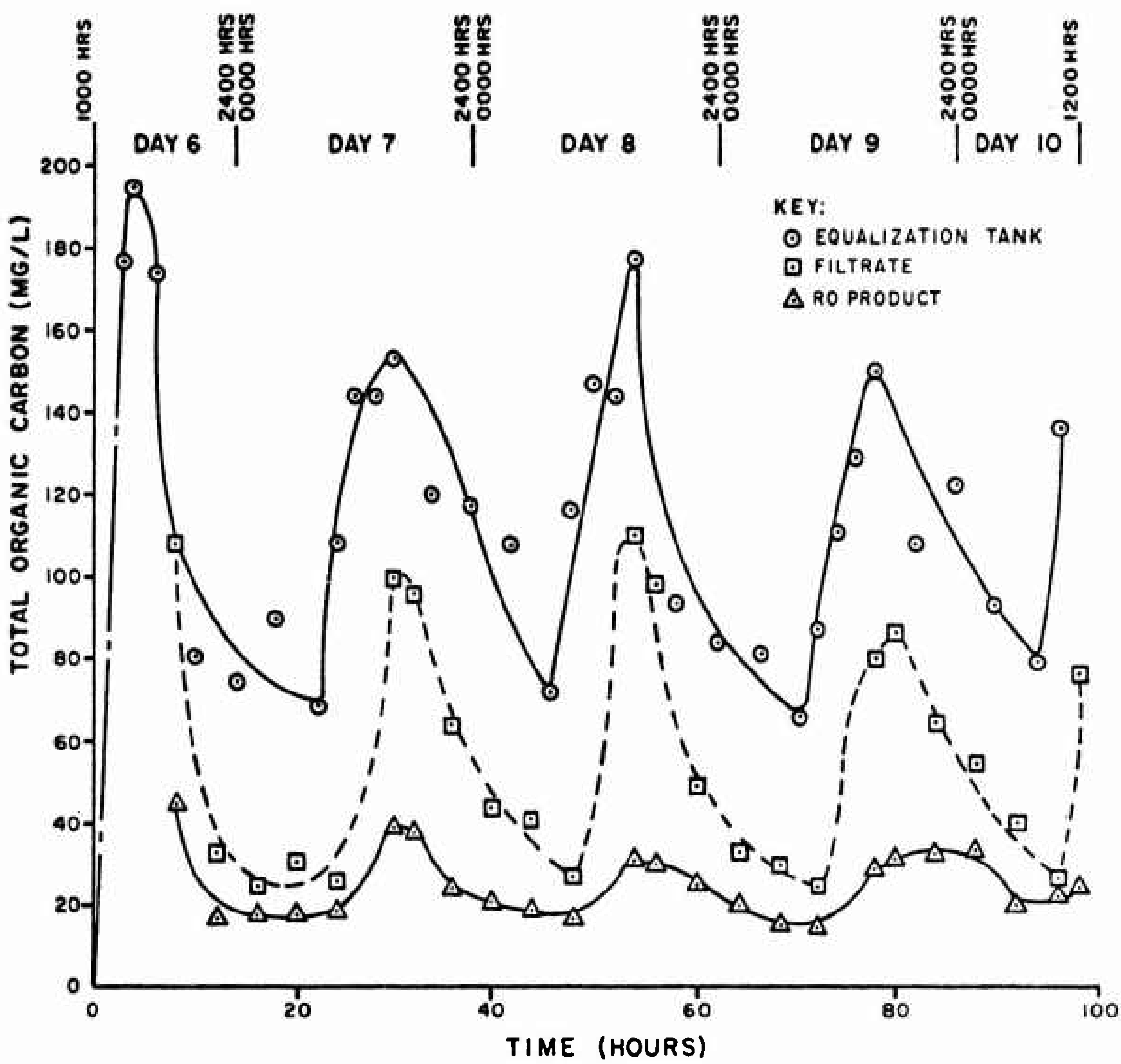

Figure 6. MUST field hospital wastewater treatment: total organic carbon versus time (week 2).

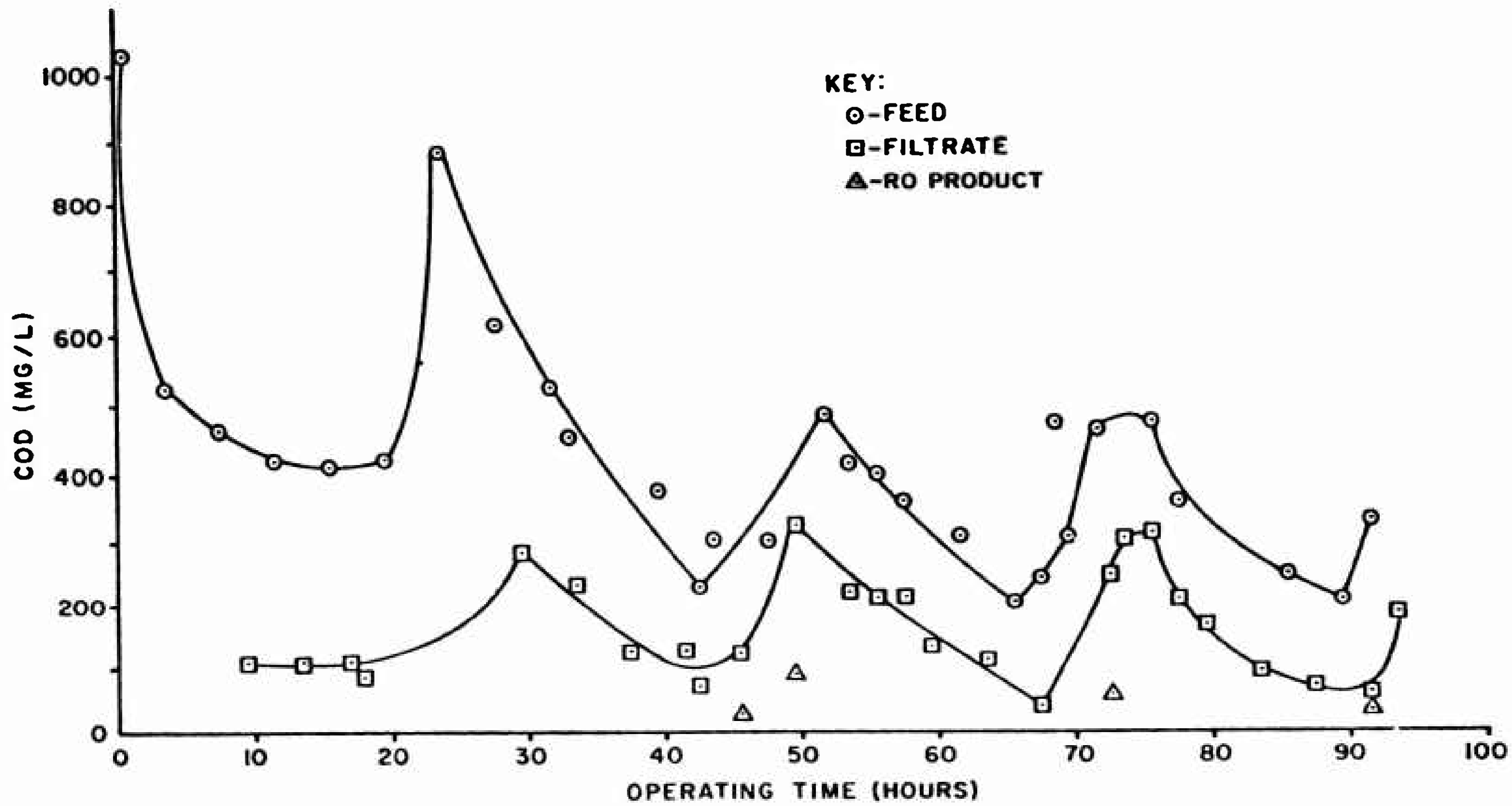

Figure 7 MUST field hospital wastewater treatment: chemical oxygen demand versus operating time (week 1: 15 April 19 April).

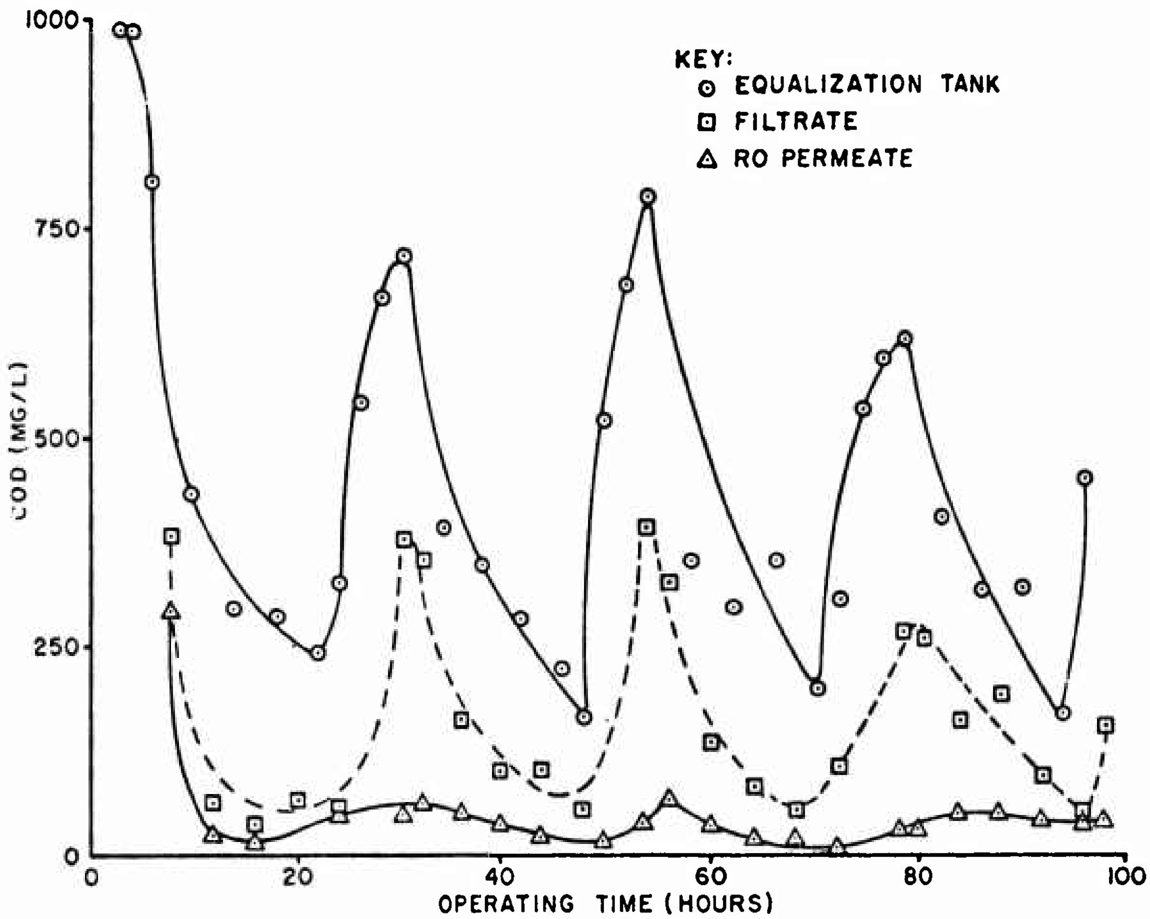

Figure 8. MUST field hospital wastewater treatment: chemical oxygen demand versus operating time (week 2: 29 April – 3 May).

approximately a 32% reduction of feedwater TOC. The reverse osmosis unit rejects the higher molecular weight components (> 200) remaining in the partially treated water, giving an average 36 mg/l TOC for the five maxima. This yields an average 74% overall TOC removal at these five maxima points based on the feedwater and 63% reduction of TOC based on the WWRU filtrate.

At the minima (composite contains a preponderance of shower water), a relatively low concentration of high-molecular-weight compounds exists and RO performance diminishes. Many low-molecular-weight compounds can "bleed" through the membrane. In this case, the WWRU accounts for over 60% TOC removal based on the feedwater composition, while the RO unit removes an additional 15% of TOC on the same basis. In contrast, the RO unit performance at the maxima accounted for an average 44% of TOC reduction.

As expected, the COD graph corresponds qualitatively to the TOC versus time graph. The COD maximum of the RO permeate for week 2 is 65. For most of this run, however, the COD was below 50, representing a substantial reduction from the feed COD maxima of 620-785. The average and range of COD minima and maxima are tabulated in Table 12. A review of the data shows that at the higher feed COD's, the reverse osmosis step removes proportionally more COD than the adsorption-coagulation-filtration step. At the minima, RO system performance is somewhat diminished for the same reasons discussed previously.

The COD data for week 1 is not as consistent or informative as for week 2 because the kitchen feedwater was varied in order to ascertain the reason for coagulation difficulties.

The relationship between COD and TOC is plotted in Figure 9. The linear correlation coefficient, r, was computed for the COD-TOC data for feed, filtrate, and RO permeate for the 2 weeks (separately and combined). This coefficient measures the linear relationship between the two variables. The results are tabulated in Table 13. The square of the correlation coefficient is a measure of the percentage of the variance in the dependent variable that is accounted for by correlation. Thus, the data show that the correlation accounts for over 50% of the variance in COD for these waters. COD and TOC are not perfectly correlatable because they do not measure exactly the same substances. COD fails to detect many straight chain aliphatic and aromatic hydrocarbons,[5] while TOC does not measure oxidizable inorganics and organic nitrogen detectable by COD. Since COD is an oxygen-demanding parameter and TOC is an index of the organic carbon in the water, the ratio of COD to TOC is an indication of the amount

[5] J. Zajic, O. Spacek, and V. Strnzic, "BOD and COD Analyses on Paraffinic Hydrocarbons," J.A.W.W.A., 62: 12 Dec. 1970, pp. 784-785.

Table 12. Range of Values for TOC and COD

	TOC		COD	
	Range	Average	Range	Average
Week 1				
Minima				
Feed	51-63	58	206-412	266
Filtrate	17-28	23	44-86	67
RO Permeate	14	14	32	32
Maxima				
Feed	105-117	111	475-884	614
Filtrate	72-110	91	286-326	308
RO Permeate	32-47	40	92	92
Week 2				
Minima				
Feed	66-79	72	165-245	195
Filtrate	24-27	26	40-65	50
RO Permeate	14-20	17	10-15	13
Maxima				
Feed	150-177	160	620-785	708
Filtrate	86-110	99	270-390	345
RO Permeate	31-39	34	50-65	58

Table 13. Relationship Between COD and TOC for MUST Waters

Wastewater Type	Number of Points	Correlation	Correlation Coefficient
Feed – Week 1	28	COD=4.04TOC+11.2	0.87
Feed – Week 2	29	COD=6.06TOC-248	0.92
Combined Feed	57	COD=4.95TOC-96.8	0.89
Filtrate – Week 1	26	COD=3.11TOC+3.66	0.96
Filtrate – Week 2	24	COD=3.92TOC-53.9	0.97
Combined Filtrate	50	COD=3.54TOC-25.5	0.96
RO Permeate – Week 2	22	COD=1.60TOC-3.03	0.74

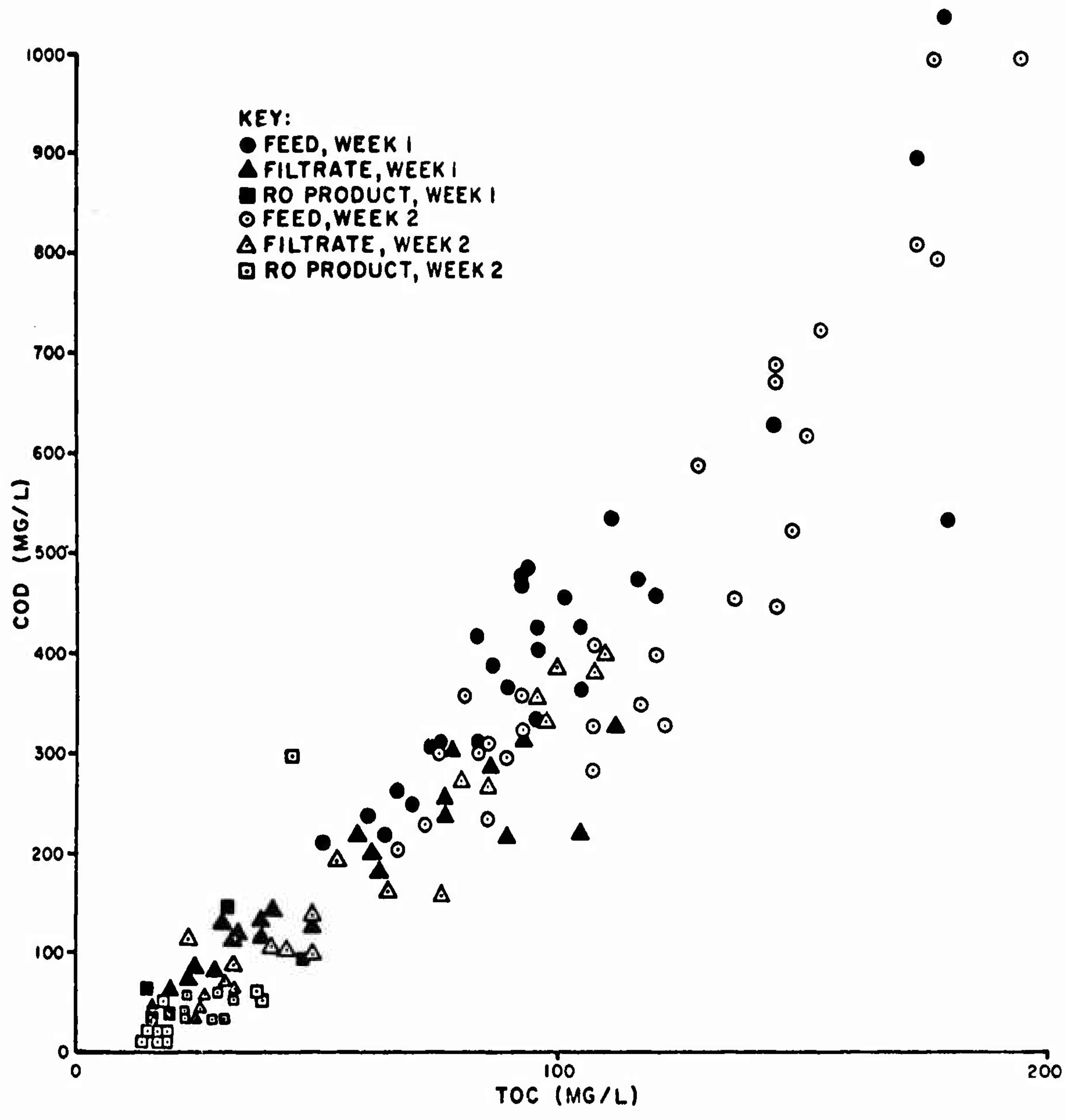

Figure 9. MUST wastewaters: chemical oxygen demand versus total organic carbon.

of oxidizable material making up the total organic matter in the water. This ratio is referred to as "oxidation state" of the organics by Esmond and Wolf.[6] COD/TOC is plotted versus time for each week with feed, filtrate, and RO permeate as parameters (Figures 10 and 11). For week 1, the maximum feed COD to TOC ratio is 5.1 corresponding to the time before shower wastewater begins pumping into the system. The kitchen, lab, and X-ray waters predominate at this point. The minima in the feed correspond to a predominance of shower waters. The average feed COD to TOC ratio is 4.2. The filtrate COD/TOC generally shows a moderate level of reduction for week 1 with an average of 3.2. RO data are not extensive enough to plot for week 1. Week 2 data show an average feed COD/TOC of 3.8. Filtrate and RO averages are 2.7 and 1.5 respectively, giving an overall indication of treatment success based on an average index of the "oxidation state" of the organic carbon present.

An interesting comparison of process variables can be made by computing the ratio of COD of the process water at a specified point in the system compared with the original TOC present. Results taken from the smoothed data for week 2 are shown in Table 14. The figures illustrate a dramatic decline in comparative "oxidative state" of the organics. The COD data are adjusted for retention time in the system for a more meaningful comparison with the feed TOC.

c. **Reverse Osmosis.** Figures 12 and 13 show the membrane flux and salt rejection versus operating time for the reverse osmosis section. The unit was operated at an average recovery rate of 91.5% with an average feed TDS of 893 mg/l. The most significant period of decline in both flux and salt rejection occurs between 55 and 73 hours of operating time. During this interval, the membrane flushing was not executed properly since the feed pressure was not sufficiently reduced. Solids buildup caused by concentration polarization took place at the membrane interface thus leading to a precipitous drop in both flux and rejection. As soon as flushing became more frequent and thorough (2-minute flush each hour), salt rejection properties of the membrane were restored to a large extent. This shows that the constant threat of membrane fouling at high recovery can be substantially overcome by proper flushing.

As a precautionary measure, the membranes were cleaned several times during the second week's run. The buffered cleaning solution contained a quaternary ammonium compound, phosphoric acid, and a cleaning agent. The solution was recirculated for 10 minutes and replaced by a tap water rinse for an additional 10 minutes. This occurred at 80, 104, and 128 hours on the operating time chart. It is not apparent that these treatments had any effect on flux or salt rejection.

---

6 S. E. Esmond, and H. W. Wolf, "The Status of Organics. . . ." Proceedings of the 15th Water Quality Conference, Univ. Illinois, Feb. 1973, pp. 91-99.

Table 14. Comparison of COD in the System to Original TOC
(Week 2)

Time (hr)	$\frac{COD_{feed}}{TOC_{feed}}$	$\frac{COD_{filtrate+2}}{TOC_{feed}}$	$\frac{COD_{RO+2}}{TOC_{feed}}$
6	4.65	2.18	1.69
11	4.25	.96	.27
16	3.85	.77	.26
21	2.72	.72	.50
26	4.17	1.27	.43
31	4.28	1.71	.39
36	3.08	1.50	.35
41	3.00	.89	.32
46	2.78	1.11	.21
51	4.41	1.84	.21
56	5.12	1.68	.40
61	4.72	1.11	.22
66	3.72	.81	.13
71	4.66	1.64	.14
76	5.07	1.82	.22
81	3.65	1.47	.38
86	3.10	1.39	.46
91	2.47	.95	.45
96	3.19	1.13	.32

NOTE: +2 indicates that the Filtrate and RO readings were taken 2 hours later than the operating time indicated for the feed readings.

In general, the salt-rejection properties of the membrane showed little deterioration over the life of the test. During the last several days of experimentation, salt rejection hit a low of 79% at one point but was above 84% for a majority of the last 65 hours of operation. The data compare favorably with the 86 to 94% rejection rates exhibited in the first 45 hours.

The flux data show a more erratic and less dramatic recovery after the 2-minute flushes were begun. During the initial 45 hours, flux was between 14 and 16 gf^{2}d. After the recovery from poor flushing (73 hours operating time), flux slowly trended upward, varying between approximately 9.5 and 14.5 gf^{2}d.

d. **Refractory Compounds.** Some cursory work was done to investigate the effect of oxidation on the refractory compounds in the RO permeate. Potassium permanganate and also ozone were utilized to treat the permeate. Concentrations of

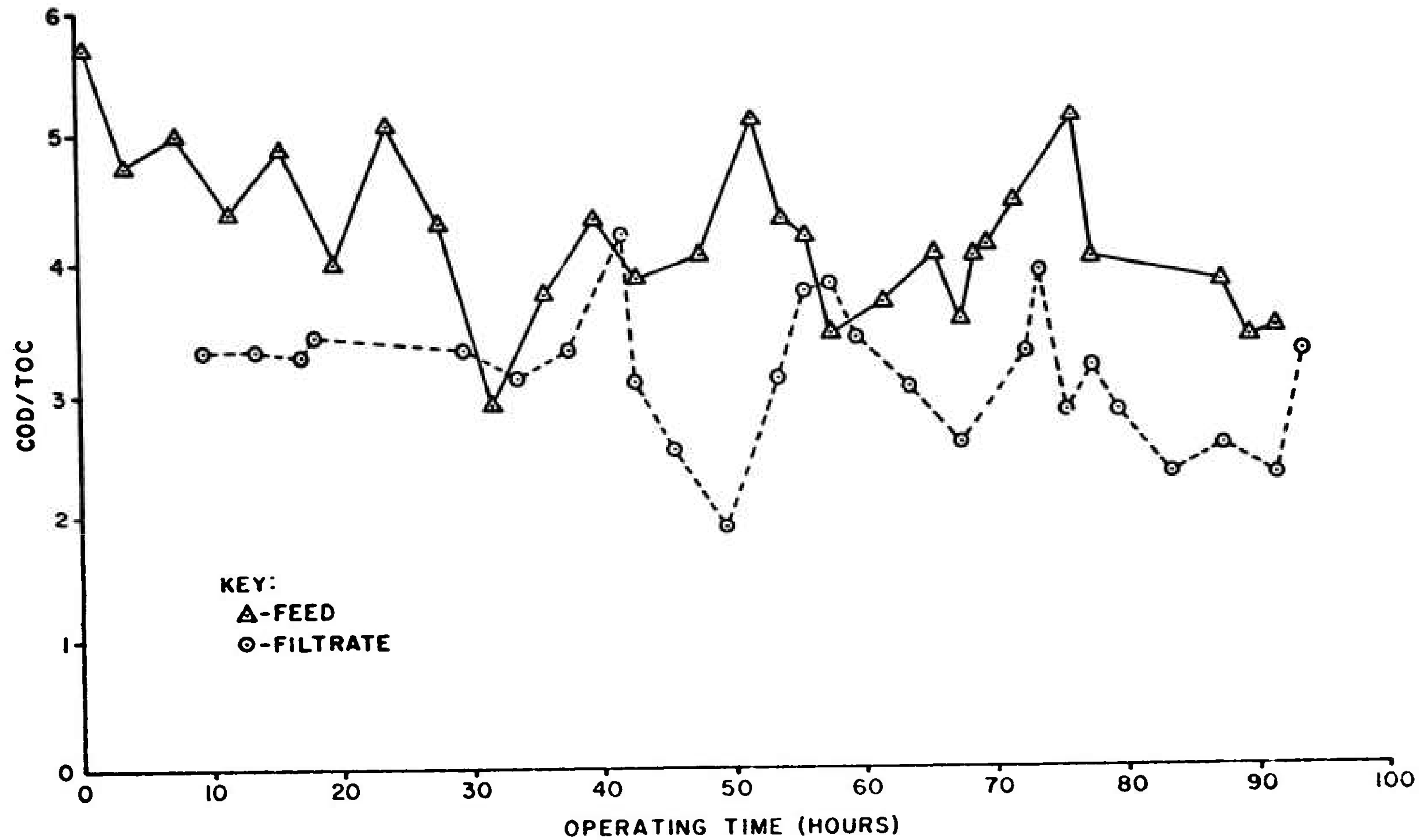

Figure 10 Ratio of COD to TOC versus operating time (week 1: 15 April – 19 April).

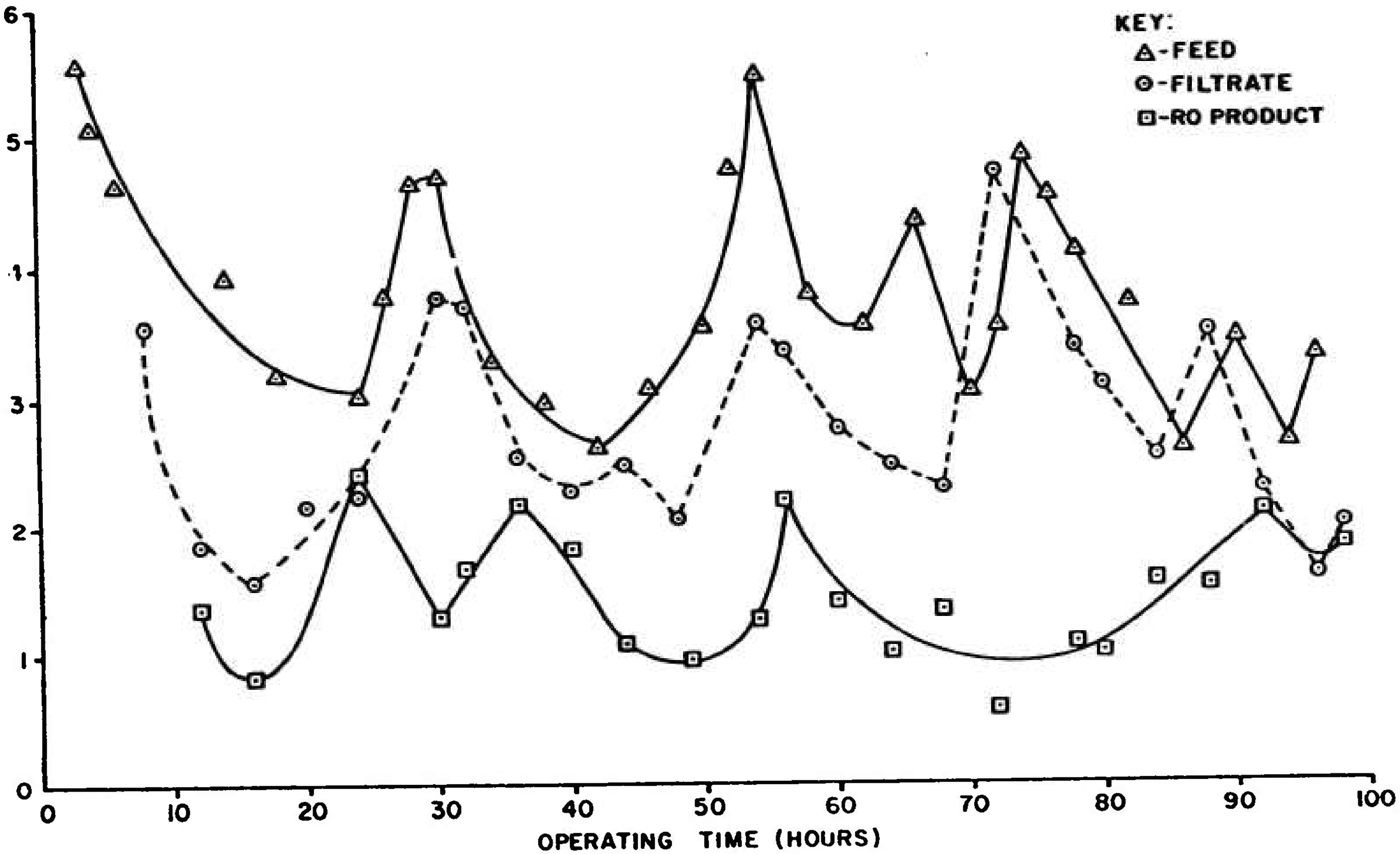

Figure 11. Ratio of COD to TOC versus operating time (week 2: 29 April – 3 May).

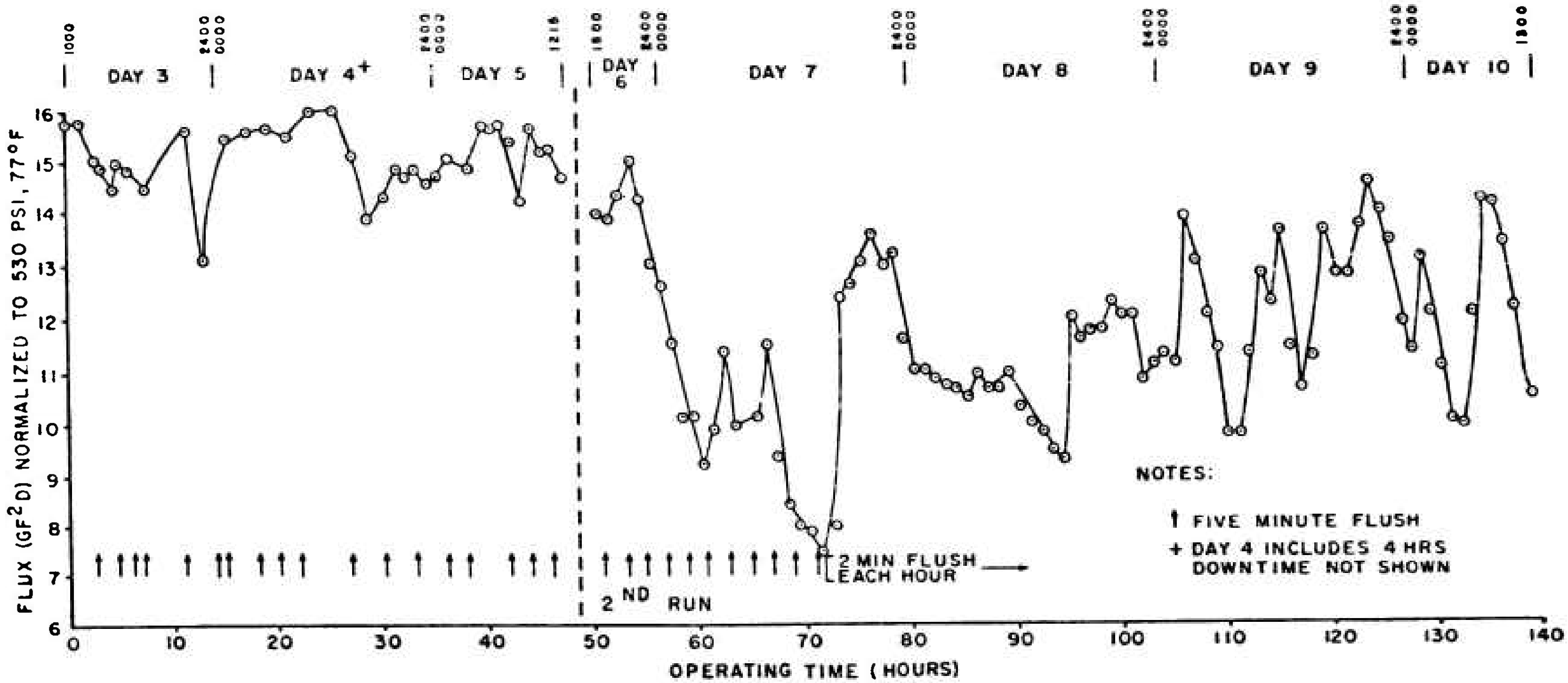

Figure 12. MUST wastewater treatment: reverse osmosis flux versus operating time.

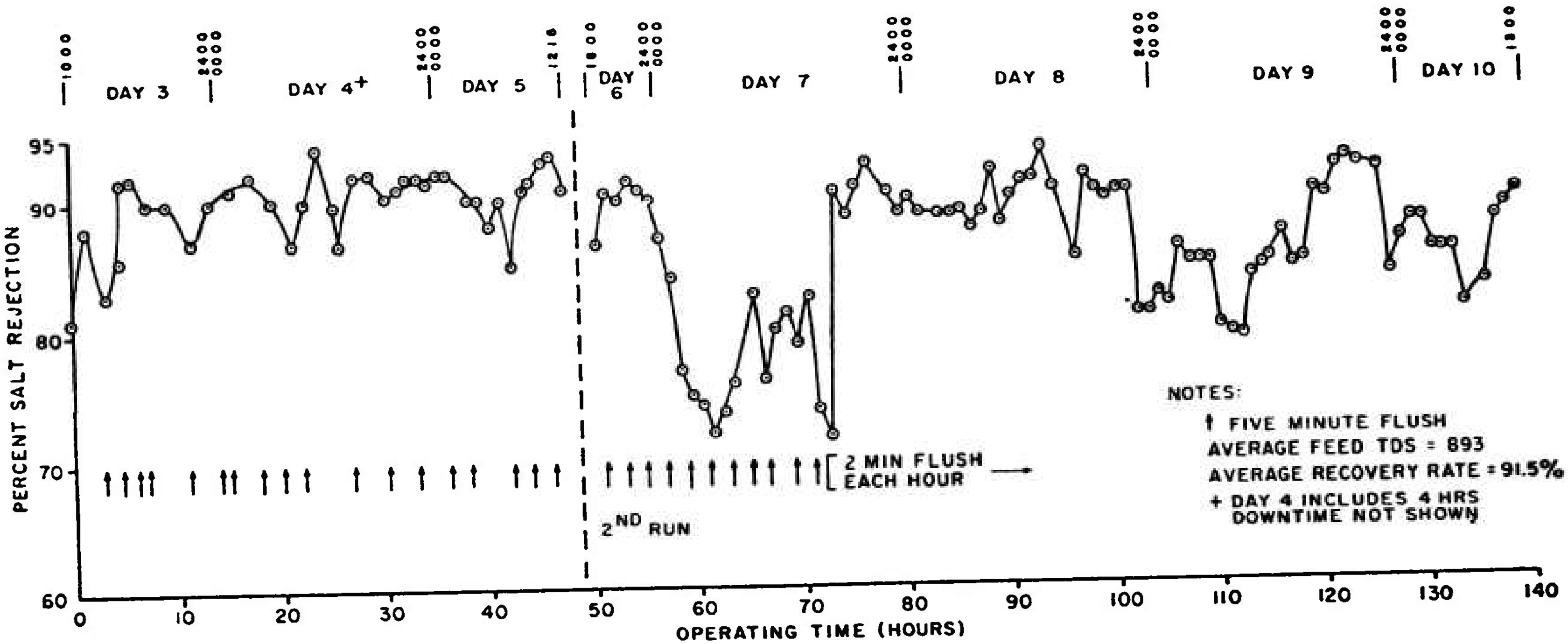

Figure 13. MUST wastewater treatment: reverse osmosis salt rejection versus operating time.

$KMnO_4$ were varied from 250 mg/l to 2000 mg/l in the jar tests. A mix time of 30 minutes at 30 rpm on a gang stirrer was employed. Thirteen separate RO permeate samples from the second week were combined to create a composite test solution. Upon treatment, only the samples containing 1500 and 2000 mg/l $KMnO_4$ showed a significant TOC reduction. COD determinations were made for these two samples, yielding a reading of zero in each case. No TOC in the 2000 mg/l $KMnO_4$ sample was detected.

A brief ozonation experiment was carried out in a well-stirred batch reactor at 50°C using ultraviolet light as a catalyst.[7] The results show a marked initial reduction in TOC followed by its gradual rise (Table 15). Even after a long contact time, a good deal of refractory material remains. Complete oxidation of the organics to carbon dioxide and water was not approached. This indicates some of the difficulties inherent in achieving complete reuse of the water.

Table 15. Ozonation of Reverse Osmosis Permeate

Time (min)	TOC (mg/l)	O_3 (mg/l)	pH
0	27.1	–	7.40
60	4.7	–	4.50
120	9.3	–	7.45
240	9.6	–	7.40
480	11.4	43.0	7.20

NOTE: – No data.

A determination of the quantity and nature of organic contaminants in the RO permeate was attempted by a subcontractor.[8] The study indicated that no significant levels of low-molecular-weight organic compounds could be detected. Another such study, however, is being conducted by the U.S. Army Biomedical Research and Development Laboratories to be completed soon. In general, one would expect the TOC of the RO permeate to consist of a relatively high amount of low molecular weight compounds.[9] Table 16 is a partial compilation of organic compounds which are commonly found in wastes from hospital sources. The list, prepared by E. Chian, University of Illinois, indicates that there are many very soluble organics which are of sufficiently low molecular weight to pose a difficult rejection problem for high-recovery RO.

[7] Houston Research, Inc., Private Communication to J. Vlahakis, July, 1974.

[8] Hazleton Laboratories, Private Communication to USAMERDC, Fort Belvoir, Virginia, June, 1974.

[9] L. H. Reuter, "The Occurrence, Significance, and Control of Organics in Direct Wastewater Reuse Systems," Paper presented at 15th Water Quality Conference, Univ. Illinois, Feb., 1973.

Table 16. Organic Compounds Commonly Occurring in Hospital Wastewater (from L. H. Reuter)

Compounds	MW	Solubility	Toxicity	Sources
(1) Alcohols				
Methyl –	32	∞	3	Solvent
Ethyl –	46	∞	2	Solvent
Iso-propyl –	60	∞	3	Rubbing alcohol
Butyl –	74	s	3	Solvent
Amyl –	88	i	3	Solvent
(2) Acids				
Hydrocyanic (HCN)	27	∞	6	Metal polish, insecticide, rotenticide, fungicide
Cyanic (HOCN)	43	s	3	Insecticide, rotenticide
HCOOH	46	∞		Disinfectant
Acetic	60	∞		Disinfectant, stop-bath
Oxalic	90	s	4	Bleach, metal cleaner
Lactic	74	∞		
Stearic	285	i	1	Basic ingredient of cream and lotion
Critic	176			
(3) Aromatic Compounds				
Benzene	78	δ	4	Solvent
Toluene	92	i	4	Solvent
Xylene	106	i	4	Solvent
Anilene	93	s	4	Solvent
Phenol	94	s	4	Disinfectant
Cresol	108	δ	4	Disinfectant
DDT	355		4	Insecticide, rotenticide
4-nitrophenol	139	1.6g/100cc	4	Fungicide
2-4 dinitrophenol	184	0.6g/100cc	4	Fungicide
Hydroquinone	110	s	4	Photo developer
Alkyl benzene sulfonate				Largest class of anionic surfactant
Naphthalene	128	i		Deodorizer
p-di-Cl-benzene	147	i	3	Moth ball, insecticidal fumigant
Monomethyl-P-amino Phenol Sulfate (Elon)			4	Photo developer
Hexachlorophene			6	Disinfectant
(4) Miscellaneous Solvents				
CCl_4	154	i	4	
CS_2	76	sl	3	
Acetone	58	∞	3	

Table 16. Organic Compounds Commonly Occurring in Hospital Wastewater (Cont'd.)
(from L. H. Reuter)

Compounds	MW	Solubility	Toxicity	Sources
(5) Others				
Methyl thiocyanate	73	δ		Pesticide, insecticide
Ethyl thiocyanate	87	i		Pesticide, insecticide
1-propyl thiocyanate	101	i		Pesticide, insecticide
BHC	290	i	4	Pesticide, insecticide
QAC			3-4	Pesticide, insecticide, disinfectant
DEET				Insect repellent
Na diethyl barbiturate	184	δ		Sedative, hypnotic agent
$Na_2C_2O_4$ (oxadate)	134	3.7g/100cc	4	Bleach, metal cleaner
Formaldehyde	30	s	3.4	Deodorizer, fumigant, photo-laq-hardener
Urea	60	vs		Cesspool
Chloroform	119	δ	3	Anesthetics, liniment
Ether	74	s	3	Anesthetics, liniment
Alkyl sulfate				Surfactant
2-terpineal	154	δ	3	Pine oil, disinfectant, floor cleaner
d-sorbital (70%)	182	s		Hand lotion
Glycersol	92	∞	1	Shampoo

Legend

Toxicity: 1-6 (6 being highly toxic)

Solubility:
∞ - all proportion
s - soluble (or vs, very soluble)
i - insoluble
sl - slightly soluble
δ - trace

Specifically, compounds like acetic acid and ethanol are representative of organic substances which pass through RO membranes. We have supported research (Figures 14 and 15) which shows the effect of ozone and ultraviolet light on the degradation of each of these organics in a batch reactor at approximately 30°C.[10] Ozone with ultraviolet light (0.4 watt/l) totally oxidized 100 mg/l acetic acid in 4 hours; whereas, ozone alone was unable to oxidize the acetic acid in 10 hours. Ozonation of 100 mg/l ethanol solution without UV showed that the TOC decreases very slowly, while the ethanol concentration decreases comparatively quickly. This is due to the formation of intermediate oxidation products between the initial compound of ethanol and the final oxidation products of carbon dioxide and water. As the oxidation takes place, a series of consecutive reactions occurs until complete oxidation is accomplished. The effect of ultraviolet light in this case is to substantially increase the reaction rates

[10] C. G. Hewes, *et al.*, "Oxidation of Refractory Organic Materials by Ozone and Ultraviolet Light," Houston Research, Inc., Final Report to USAMERDC, November, 1974.

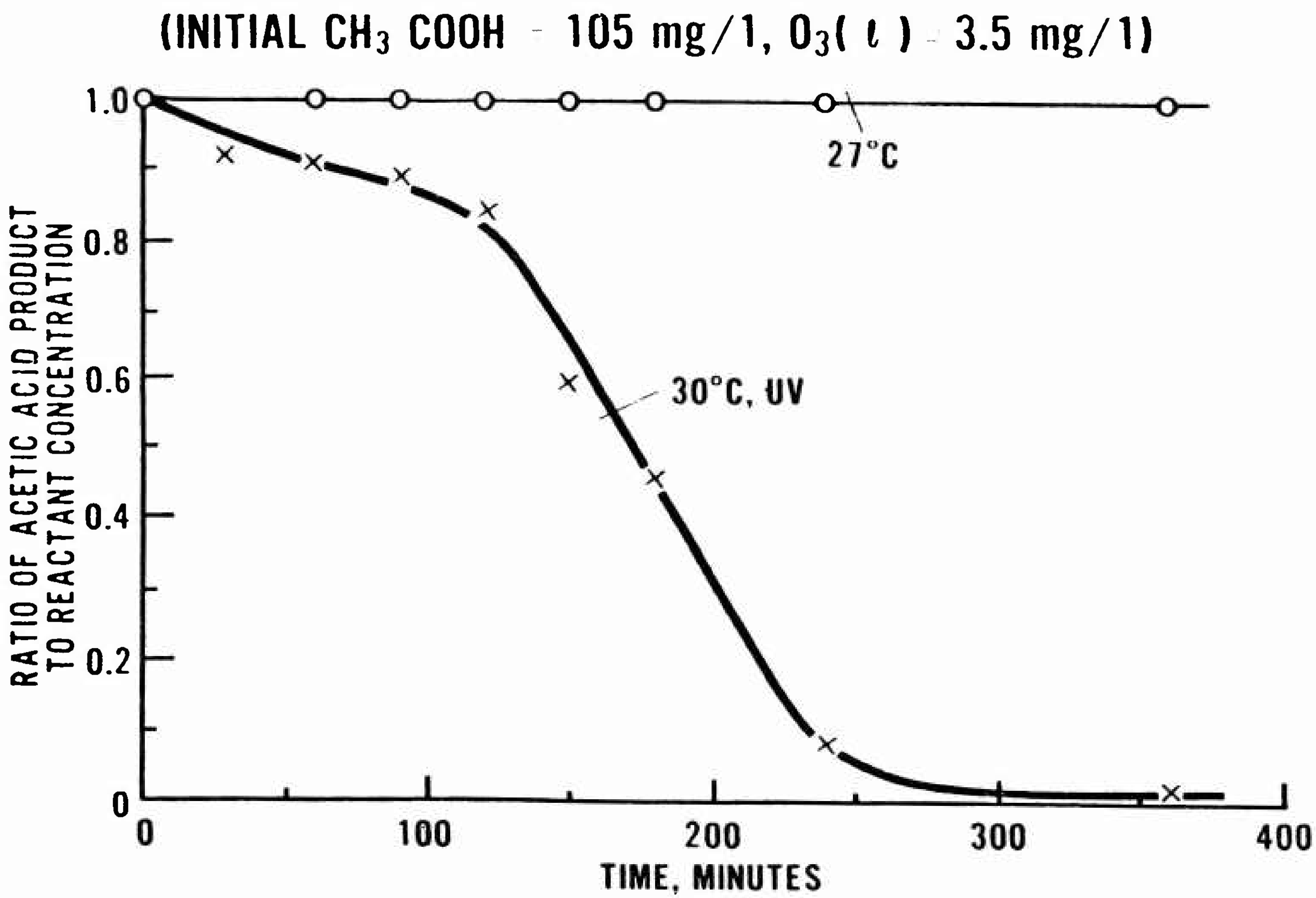

Figure 14. O_3 oxidation of acetic acid, effect of UV (from C. G. Hewes, et al.).

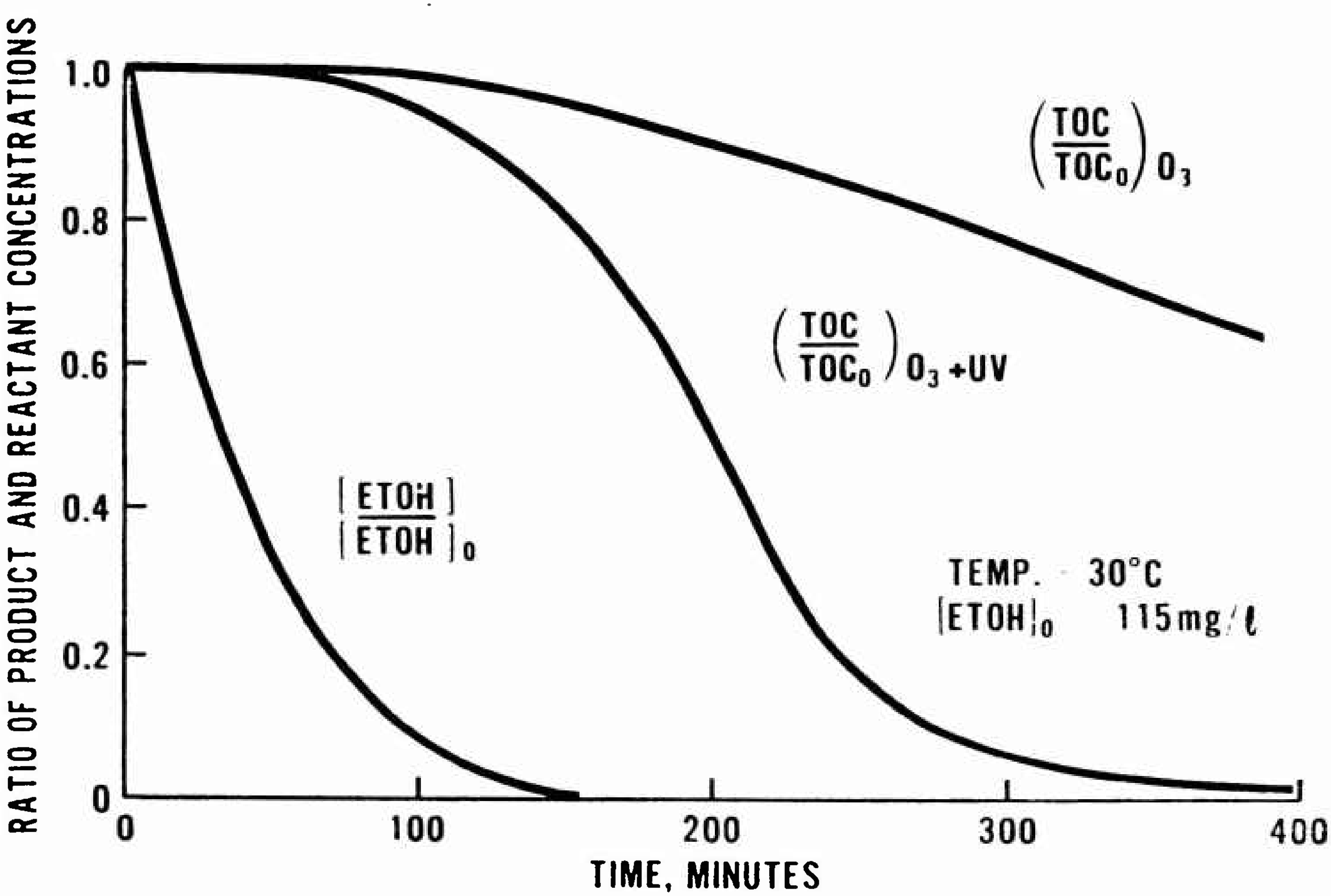

Figure 15. The effect of UV on ozone oxidation of ethanol solution (from C. G. Hewes, et al.)

of the partial oxidation species remaining in solution while having no apparent effect on the ethanol depletion. This is evidenced by a more abrupt decrease in TOC.

As might be expected, then, catalyzed ozonation of specific, single organics in distilled water is a simpler task than treating a mixture of such compounds in solution.

IV. DISCUSSION

6. **General.** The field experiments showed that wide variations in raw-water quality could be treated by the system without changes in the carbon-polymer dosages. A key element in the treatment scheme was the use of an equalization tank to help dampen the fluctuations in water quality. Our results showed that as the water quality values for TOC and COD rose sharply as a function of time, the performance of the carbon-polymer treatment diminished relative to the reverse osmosis unit. If the water quality parameters had not been reduced to reasonable levels by the equalization tank, the reverse osmosis unit would have been required to remove most of the dissolved organic contaminants. The resultant increased loading on the membrane would allow more pollutants to "bleed" through the RO.

The most serious problem in relation to the carbon-polymer treatment arises from the use of Sparkleen. Sparkleen contains sodium hexametaphosphate which is a nonprecipitating water conditioner forming soluble complexes with positively charged calcium and magnesium ions. Sparkleen was designed to combat precipitation in washing operations to prevent scum and scale. Other workers[11 12] have reported similar coagulation difficulties in the presence of the complex phosphates when using alum. Culp and Stoltenberg[13] stressed that the polyphosphates may have a significant effect on colloidal behavior. This is true because the synthetic detergents are excellent dispersing and deflocculating agents. It is also possible that the addition of large amounts of Sparkleen will allow the hexametaphosphate anion to compete with powdered carbon and turbidity particles for the positively charged sites of the added polyelectrolyte. These actions markedly decrease the effectiveness of the cationic polymer. This was confirmed in the jar tests. When the appropriate amount of Sparkleen was added to composite 800, the Cat-Floc dosage had to be increased from 25 mg/l to 100 mg/l to attain comparable treatment. The composite sample contained only 19% kitchen water.

---

11 W. F. Langelier, H. F. Ludwig, and R. G. Ludwig, "Flocculation Phenomena in Turbid Water Purification." Proc. ASCE, *78*, Separate No. 118 (Feb. 1952).

12 R. S. Smith, J. M. Cohen, and G. Walton, "Effects of Synthetic Detergents on Water Coagulation." Jour. AWWA. *48*, pp. 55-69 (Jan 1956).

13 R. L. Culp and H. A. Stoltenberg, "Synthetic-Detergent Pollution in Kansas." Jour. AWWA, 45, pp 1187-1195, (Nov. 1953).

Further studies are required to investigate effective carbon-polymer dosage ranges as well as the periodic appearance of a reddish color in the coagulated product. The color could not be reproduced in the laboratory and appeared only during the daytime in the field. The brevity of the field testing did not lend itself to a study of varying chemical dosages.

7. **Energy Cost.** We can compare the approximate operating costs of the reuse system with the costs of hauling in fresh water. The following tabulation shows the system components and corresponding power requirements:

Component	Power (kW)
Mix Tank Stirrer	0.2
Clarifier, Filter	2.6
Carbon Slurry Feeder	0.4
Reverse Osmosis Pump	3.7
TOTAL	6.9

This is equivalent to 1339 kW-hr of energy for 194 hours of total operation. At an average residential cost of $0.027/kW-hr, this amounts to $0.50/1000 gallons raw wastewater (18.4 kW-hr/1000 gallons). For the second week of operation, 676 kW-hr of energy were theoretically required. Based on final product water, the energy costs were $0.55/1000 gallons for the second run (20 kW-hr/1000 gallons). Chemical costs were $1.47/1000 gallons raw water for carbon, based on $0.19/lb, and $0.43/1000 gallons raw water for polymer, based on $0.50/lb. Total chemical costs are about $1.90/1000 gallons raw wastewater, or $2.25/1000 gallons of final product water for the second run. Total operating costs were approximately $2.80/1000 gallons of final product water.

A 400-bed hospital facility would require 45,000 gallons/day, or 45 truck-loads of fresh water per day. Truck mileage is 5 miles/gallon and gasoline cost to the government is $0.17/gallon. On the basis of a 100-mile round trip, energy cost alone is $153/45,000 gallons fresh water (900 gallons gas), or $3.40/1000 gallons. To evaluate the energy requirement:

900 gallons of gasoline	= (0.75) (8.34 #/gallon) (18,000 Btu/#) 900 gallons
	= 101,331,000 Btu
	= 29,669 kW-hr
∴ energy/1000 gallons product	= 659 kW-hr/1000 gallons

On an energy basis, this is a factor of 33 times greater than the reuse system. Of course,

this factor is directly proportional to the assumed round-trip mileage. The comparison does not take account of sludge disposal which could represent a large energy expenditure.

V. CONCLUSIONS

8. **Conclusions.** It is concluded that:

a. The system comprising polyelectrolyte-aided-carbon coagulation, upflow, solids-contact clarification, and diatomaceous earth filtration is an acceptable pretreatment for a high-recovery reverse osmosis unit in treating MUST field hospital wastewater. Sparkleen acts as an anti-coagulant, however, and must be omitted from the kitchen wastewater.

b. Dosages of 1000 mg/l Nuchar A and 100 mg/l Cat-Floc successfully treated MUST wastewater in the field unit.

c. An average recovery rate in excess of 90% can be utilized in the reverse osmosis (RO) section with the spiral-wound unit.

d. The Wastewater Reclamation Unit combined with the RO unit can achieve reductions in average turbidity from approximately 30 JTU to 0.3 JTU, average TOC from over 100 mg/l to 25 mg/l, and average COD from 445 mg/l to about 50.

APPENDIX A

MUST WASTEWATER FORMULA

Waste Element	Amt (1X) Comp 180 Gal Batch		Amt (8X) Comp 360-Gal Batch		Price/Unit		Cost 360 Gal (8X)
Silver Chloride	5.6	grams	89.8	grams	108.22	per lb	21.45
Hair	80.8	grams	1292	grams		–	–
Sodium Chloride	108.9	grams	1742	grams	8.75	per 25 lb	1.35
Haema Sol	140.8	grams	2253	grams	40.50	per 30 lb	6.70
Type I Soap	157.5	grams	2520	grams		–	–
Sparkleen	144	grams	2304	grams	48.50	per 100 lb	2.47
Scouring Powder	15.75	grams	252	grams	5.12	per 630 oz	.07
Handsoap	.04	cake	.64	cake	14.76	per 72 ck	.13
Soap	22.5	grams	360	grams	9.65	per 480 oz	.26
Urea	.33	grams	5.2	grams	3.18	per lb	.04
Kaolinite	6.21	grams	100	grams	6.97	per 5 lb	.31
Talc	6.4	grams	103	grams	6.50	per 39 oz	.61
Shower Cleaner	32.6	grams	522	grams	5.10	per 630 oz	.15
Hair Oil	51.0	grams	816	grams	8.44	per 72 oz	3.38
Hair Gel	12.1	grams	194	grams	4.54	per 18 oz	1.72
Shampoo	1.6	grams	26.3	grams	5.00	per 192 oz	.03
Toothpaste	12.1	grams	194	grams	7.84	per 72 oz	.75
Deodorant	.33	grams	5.2	grams	6.78	per 12 oz	.11
DEET	.33	grams	5.2	grams	6.83	per 192 oz	.01
Mouthwash	.64	grams	10.3	grams	.78	per 12 oz	.03
pHisohex	7.	grams	112.	grams	6.48	per 30 oz	.85
Hair Dye	.33	grams	5.2	grams	1.44	per oz	.26
Hair Coloring	.33	grams	5.2	grams	1.22	per oz	.22
Lard	8.35	grams	133.6	grams	9.60	per 48 lb	.06
Vegetable Oil	12.5	grams	200	grams	10.79	per 146 oz	.17
Lysol	2.25	ml	36.	ml	6.08	per 300 oz	.04
Betadine	141.	ml	2256.	ml	18.00	per gal	11.80
Wescodyne	26.6	ml	425.6	ml	5.45	per gal	.62
Methyl Alcohol	14.4	ml	230.4	ml	3.78	per pint	1.85
Acetone	4.5	ml	72.	ml	1.33	per pint	.21
Dichromate	45.	ml	720.	ml	6.48	per gal	1.23
Developer	739.	ml	11.8	liter	45.45	per 5 gal	28.40
Fixer	739.	ml	11.8	liter	17.05	per 5 gal	10.69
Wright Stain	4.95	ml	79.2	ml	28.00	per gal	.59
Giemsa Stain	5.4	ml	86.4	ml	24.00	per gal	.55
Crystal Violet Stn.	.9	ml	14.4	ml	5.10	per qt	.08
Safranin	.9	ml	14.4	ml	4.65	per qt	.07
Immersion Oil	.45	ml	7.2	ml	6.00	per pt	.09
Ether	.45	ml	7.2	ml	1.60	per pt	.02
$ZnSO_4$ solution	.45	ml	7.2	ml	1.74	per lb	.01

Must Wastewater Formula (Cont'd)

Waste Element	Amt (1X) Comp 180 Gal Batch		Amt ((8X) Comp 360-Gal Batch		Price Unit		Cost 360 Gal (8X)
KI-I alcohol soln	.9	ml	14.4	ml	2.04	per 4 oz	.04
Thiolglycolate soln	14.85	ml	237.6	ml	3.39	per 100 gm	.45
5% Phenol	11.25	ml	180.	ml	4.21	per lb	.08
22.2% Na_2SO_4	.9	ml	14.4	ml	1.28	per lb	.01
10% Formaldehyde	.9	ml	14.4	ml	1.23	per pt (40%)	.01
30% Sulfosal. Acid	.9	ml	14.4	ml	2.95	per 4 oz	.11
.1N NaOH	16.2	ml	259.2	ml	2.08	per lb	.01
30% Trichloracet Ac	.7	ml	11.2	ml	2.62	per 4 oz	.08
Diazo Blank	.7	ml	11.2	ml	.01	per 100 ml	.01
HOCl Reagent	.9	ml	14.4	ml	.48	per 500 ml	.01
Buffered Subst.	.9	ml	14.4	ml	.35	per 100 ml	.06
Bilirubin Std.	.9	ml	14.4	ml	16.93	per gm	.20
.85% NaCl	25.1	ml	402.	ml	.01	per 100 ml	.04
O-toluidine Reagent	2.5	ml	40.	ml	1.10	per l	.01
Diazo Reagent	.45	ml	7.2	ml	.01	per 100 ml	.01
Biuret Reagent	1.35	ml	21.6	ml	1.77	per l	.04
DNPH Reagent	.45	ml	7.2	ml	2.60	per 25 gm	.01
Phenol Reagent	1.1	ml	18.0	ml	.30	per 100 ml	.05
2% Sodium Citrate	.45	ml	7.2	ml	.05	per 100 ml	.01
Agar	8.3	ml	132.8	ml	.45	per 66 ml	.90
Chocolate Agar	14.85	ml	237.6	ml	.95	per 118 ml	1.90
EMB Agar	14.85	ml	237.6	ml	1.05	per 118 ml	2.10
Blood Agar	14.85	ml	237.6	ml	.95	per 118 ml	1.90

	180 Gal	360 Gal	1200 Gal	4200 Gal	
Costs – 1X Batch	3.03	6.07	20.25	70.60	48.54
– 8X Batch	24.27	48.54	162.00	565.00	

APPENDIX B

MUST WATER JAR TESTS

X-Ray Waste

		Atlasep			Turbidity		
Carbon	Cat-Floc	105C	1A1	2A2	(JTU)	TOC	
1000	10	-		-	2.2	-	
1000	30				2.8	–	
1000	50	-		-	1.7	–	
1000	10		2.0		0.9		
1000	30		2.0	-	0.6		
1000	50		2.0		0.5	-	
1000	50				3.4	–	
1000	100				4.0		
1000	150				4.2		
The above tests were preliminary runs at different stirrer speeds than the standardized jar tests below.							
1000 N	1				4.1	1246	Raw TOC 1397
1000	1		-		3.7	1271	″
1000 N	5		–		2.3	1427	″
1000	5				1.6	1317	″
1000 N	10			–	2.1	1321	″
1000	10				1.0	1272	″
1000 N	21		2.0		0.5	1335	″
1000 N	25		2.0		0.1	1260	″
1000 N	30		2.0		0.3	1305	″
2000 N	1			-	1.7	1172	″
2000 N	5				1.9	1202	″
2000 N	10				3.7	1172	″
2000 N	21		2.0		0.4	1200	″
2000 N	25		2		0.3	1125	″
2000 N	30		2		0.3	1170	″
2000 N		1		-			
2000 N		5		–			
2000 N		10					

NOTE: Units – mg/l except as noted.
Carbon – Hydrodarco C except as noted by "N" for Nuchar A.
Average Raw Turbidity = 61 JTU.
— No Data

Shower Waste

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
500 N	1	–	–		47	93.0	Raw TOC 105.9
500 N	5	–	–		17	67.3	"
500 N	10	–	–		40	73.5	"
500 N	10	–	2				
1000 N	1	–	–		32	75.0	"
1000 N	5	–	–		22	62.0	"
1000 N	10	–	–		28	62.0	"
1000 N	10	–	2				
2000	1	–	–		13	58.0	"
2000 N	1	–	–		10	59.8	"
2000	5	–	–		12	73.3	"
2000 N	5	–	–		6.0	53.8	"
2000	10	–	–		19	65.0	Raw TOC 111.3
2000 N	10	–	–		7.4	94.5	"
2000	10	–	2		17		
2000	10	–	2		8.2		
2000	11	–	–		7.8		
2000	11	–	–		4.6		
2000	15	–	–		8.1		
2000 N	15	–	–		2.6	50.5	Raw TOC 105.9
2000	25	–	–		22	70.3	Raw TOC 111.3
2000 N	25	–	–		13	59.3	"
2000	25	–	2		24		
2000 N	25	–	2		4.3	55.0	"
2000	50	–	–		24	74.3	"
2000 N	50	–	–		22	71.0	"
2000	50	–	2				
2000 N	50	–	2		18		
2000	–	1	–		32	76.6	Raw TOC 105.9
2000 N	–	1	–		27	87.0	"
2000		3	–				
2000 N	–	3	–				
2000	–	10	–		33	75.3	Raw TOC 111.3
2000 N	–	10	–		27	76.3	"
2000	–	10	2				
2000 N	–	10	2		26		
2000	–	25	–		21	90.0	"
2000 N	–	25	–		22	92.2	"
2000	–	25	2				
2000 N	–	25	2				
2000	–	50	–		21	92.0	"
2000 N	–	50	–		19	94.5	"
2000	–	50	2				
2000 N		50	2				

NOTE: Average Raw Turbidity = 75 JTU.
Units: mg/l except as noted.

Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
– No Data.

Operating Room Waste

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
50	10		–		NC	NC	
50	20		–		18		
50	30		–		22		
50	40		–		30		
100	10		–		NC	NC	
100	20		–		17		
100	30		–		21		
100	40		–		28		
250	10		–		NC	NC	
500	10		–		NC	NC	
750	10		–		NC	NC	
1000	10		–		NC	NC	
1000	30		–		NC	NC	
1000	40		–		NC	NC	
1000	50		–		NC	NC	
1000	60		–		17		
1000	70		–		16		
1000	80		–		16		
1000	90		–		11		
1000	100		–		12		
1000	110		–		9.9		
1000	120		–		9.4		
1000	130		–		10.0		
1000	140		–		9.4		
2000	1		–		NC	NC	
2000 N	10		–		NC	NC	
2000 N	25		–		2.8	115	Raw TOC 166
2000	50		–		2.4	55	Raw TOC 106
2000 N	50		–		1.5	53.2	”
2000	100		–		2.3	65	”
2000 N	100		–		0.92	52	
2000 N	150		–		0.79	53	
2000 N	175		–		0.87	65	
2000 N	–		1		NC	NC	
2000 N	–		50		NC	NC	
2000	–		50		NC	NC	
2000 N	–		100		NC	NC	
2000	–		100		NC	NC	
2000	–		150		NC	NC	

NOTE: Units: mg/l except as noted.
Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
NC: No coagulation.
– No Data.

Laboratory Waste

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
1000	0.25	–	–		5.1		
1000	0.25	–	0.25		7.5	153.2	Raw TOC 246
1000	0.25	–		0.25	6.7		
1000	0.50	–	–		4.4	165	Raw TOC 246
1000	0.50	–		0.25	6.7		
1000	0.75	–	–		NC	NC	
1000	1.00	–	–		NC	NC	
1000	–	0.05	–		5.9	156	Raw TOC 186
1000	—	0.10	–		6.3	152	"
1000	–	0.25	–		7.2	149	"
1000	–	0.30	–		4.2		
1000	–	0.35	–		4.6		
1000	–	0.50	–		5.1		
1000	–	–	0.25		7.8	146.4	Raw TOC 245
1000	–	—	0.50		3.9	129.2	"
1000	–	–	1.00		7.1	144.0	"
1500	0.50	–	–		4.3	172	"
1500	0.50	–	0.25		5.9	150	"
1500	0.25	–		0.25	7.3		
1500	0.50	–		0.25	4.1	117.2	Raw TOC 161.2
1500	0.75	–	–		NC	NC	
1500	1.00	–	–		2.5		
1500	1.00	–	–		5.7		
1500	–	0.05	–		4.8	142	Raw TOC 186
1500	–	0.10	–		5.3	138	"
1500	–	0.25	–		5.4	130	"
1500	—	0.30	–		4.2		
1500	–	0.35	–		3.1		
1500	–	0.50	–		3.3		
2000	0.25	–		0.25	4.0	112.0	Raw TOC 161.2
2000	0.25	--	0.25		4.3	172	"
2000	0.25	–	0.50		NC	NC	
2000	0.50	–	–		5.5	NC	
2000	0.50	–	0.25		1.8	118.4	Raw TOC 246
2000	0.50	–		0.25	6.3	NC	
2000	0.50	--	0.50		NC	NC	
2000	0.75	–	–		2.6	105.2	Raw TOC 161.2
2000	1.00	–	–		5.5	NC	
2000	1.00	–	–		--	–	
2000	1.00	–	0.25		4.8		
2000	1.00	–	0.50		NC	NC	
2000	–	1	–		3.9	200	Raw TOC 272
2000	–	2	–		4.7	172	"
2000	-	10	–		6.3	198	"
2000	–	20	–		7.7	208	"

Laboratory Waste (Cont'd)

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
2000		40	–		8.7	216	Raw TOC 272
2000		100	–		10.0	230	"
2000		1	0.2		2.2		
2000		2	0.2		3.3		
2000		10	0.2		5.0		
2000		20	0.2		6.4		
2000		40	0.2		7.6		
2000		100	0.2		8.8		
2000		0.05	–		4.3	129.2	Raw TOC 186
2000	–	0.10	–		4.6	132	"
2000	–	0.25	–		4.8	121.6	"
2000	–	0.30	–		2.4		
2000	–	0.35	–		2.8		
2000	–	0.50	–		2.8		
2000	–	0.50	–		4.9	165.0	Raw TOC
2000	–	0.75	–		4.3	153.0	"
2000	–	1.50	–		4.4	153.2	"
2000 N	–	0.50	–		1.5	147.0	"
2000 N	–	0.75	–		2.1	143.0	"
2000 N	–	1.50	–		2.2	146.5	"

Note: Average Raw Turbidity = 18 JTU.
NC: No coagulation.
Units: mg/l except as noted.
Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
-- No Data

Kitchen Waste

Carbon	Cat-Floc	105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
500	1	–	–	–	NC	NC	
500 N	1	25	–	–	NC	NC	
500	25	–	40	–	NC	NC	
500 N	25	–	–	–	NC	NC	
500	50	–	–	–	NC	NC	
500 N	50	–	–	–	NC	NC	
2000	1	–	–	–	NC	NC	
2000 N	1	–	–	–	NC	NC	
2000	25	–	–	–	NC	NC	
2000 N	25	–	–	–	NC	NC	
2000	50	–	–	–	NC	NC	
2000 N	50	–	–	–	NC	NC	
2000	100	–	–	–	NC	NC	
2000 N	100	–	–	–	NC	NC	
2000	150	–	–	–	NC	NC	
2000 N	150	–	–	–	NC	NC	
2000	–	–	25	–	NC	NC	
2000 N	–	–	25	–	NC	NC	
4000 N	50	–	–	–	NC	NC	
4000 N	100	–	–	–	NC	NC	
4000 N	150	–	–	–	NC	NC	
500 N	1	–	–	–	–	NC	
500 N	5	–	–	–	–	NC	
500 N	10	–	–	–	–	–	
500 N	50	–	–	–	–	–	
500 N	100	–	–	–	–	–	
2000 N	5	–	–	–	6.1	–	
2000 N	10	–	–	–	3.3	9	Raw TOC 220
2000 N	50	–	–	–	15	–	
2000 N	100	–	–	–	7.7	–	

Note: Units: mg/l except as noted.
Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
NC: No coagulation.
– No Data.

Kitchen Waste (Cont'd)

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
		Kitchen Waste w/Sparkleen (No detergent)					
2000 N	1	–	–	–	–	NC	
2000 N	5	–	–	–	–	NC	
2000 N	10	–	–	–	–	NC	
2000 N	20	–	–	–	–	NC	
2000 N	60	–	–	–	–	NC	
2000 N	80	–	–	–	–	NC	
2000 N	100	–	–	–	–	NC	
2000 N	200	–	–	–	–	NC	
2000 N	400	–	–	–	–	NC	
		Kitchen Waste w/Detergent (No Sparkleen)					
2000 N	20	–	–	–	10	39	Raw TOC 440
2000 N	60	–	–	–	14	40	"
2000 N	80	–	–	–	16	42	"
2000 N	100	–	–	–	17	43	"
2000 N	200	–	–	–	14	45	"
2000 N	400		–	–	10	44	"
		Kitchen Waste w/Detergent and ¼ Dosage Sparkleen					
2000	20	–	–	–	–	NC	
2000	60	–	–	–	–	NC	
2000	80	–	–	–	–	NC	
2000	100	–	–	–	–	NC	
2000	200	–		–	–	NC	
2000	400	–	–	–	–	NC	

Note: Units: mg/l except as noted.
Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
NC: No coagulation.
– No Data.

Composite 1440

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC
1000 N	250	–	–	–	–	–
2000 N	1	–	(+2 aft 1 hr)	–	–	–
2000 N	10	–	"	–	–	–
2000 N	25	–	"	–	–	–
2000 N	50	–	"	–	–	–
2000 N	100	–	"	–	–	–
2000	50	–	"	–	–	–
2000	100	–	"	–	–	–
2000	150	–	"	–	–	–
2000 N	150	–	(+5 aft 1 hr)	–	–	–
2000 N	250	–	–	–	–	–
3000 N	250	–	–	–	–	–

Note: Units: mg/l except as noted.
Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
– No Data.

Composites

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC		
				3-Part Composite Without Kitchen and OR				
2000 N	5	--	—	—	4.4	128	Raw TOC	203
2000 N	10	--	—	--	5.0	108	"	
2000 N	100	—	--	—	4.4	118	"	
2000	5	--	--	-	2.3	128	"	
					Raw Turb=53			
				4-Part Composite Without Kitchen				
2000 N	5	-	—	--	3.1	67	Raw TOC	130
2000 N	25	-	—	--	4.1	71.5	"	
2000 N	100	-	--	-	3.7	71.5	"	
				5-Part Composite with/3/4 Dosage Kitchen				
2000 N	5	--	—	—	5.1	71	Raw TOC	183
2000 N	25	-	-	—	5.3	60	"	
2000 N	100		-	—	15	67.5	"	
					Raw Turb=36			
				5-Part Composite with Full Dosage Kitchen				
2000 N	1	-	-	-	—	—		
2000 N	2		-		7.0	-		
2000 N	5	-	-	-	6.3	75	Raw TOC	204
2000 N	10		--	—	8.2	67	"	

Note: Carbon: Hydrodarco C except as noted by "N" for Nuchar A.
OR: Operating Room.
-- No Data.

Composites (Cont'd)

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
Composites - Concentrations Drawn from Mass Diagram for Four Exemplary Times							
Time: 480 min from start up		I 57% OR: 43% Shower					Raw TOC 116
2000 N	1	–	–	–		–	
2000 N	5	–	–	–		–	
2000 N	10	–	–	–	–	–	
2000 N	25	–	–	–	3.8	54.6	
2000 N	50	–	–	–	3.6	49.0	
					Raw Turb-37		
Time: 800 min from start up		II 41% OR: 23% Shower; 19% Kitchen;* 12% Lab; 5% X-Ray*					Raw TOC 239
2000	10	–	–	–	23	–	
2000	25	–	–	–	23	145	
2000	50	–	–	–	23	–	
2000	100	–	–	–	23	–	
2000 N	1	–	–		–	–	
2000 N	5	–	–	–	–	–	
2000 N	10	–	–	–	–		
2000 N	25	–	–	–	11	144	
2000 N	50	–	–	–	13	137	
2000 N	100		–		14	137	
					Raw Turb 49		
Time: 1200 min from start up		III 44% Shower: 30% OR: 12% Kitchen;* 10% Lab: 4% X-Ray *					Raw TOC 195
2000 N	1						
2000 N	5						
2000 N	10				–		
2000 N	25				13	91	
2000 N	50				18	92	
2000 N	100				15	86	
					Raw Turb 52		
Time: 1440 min from start up		IV 50% Shower: 26% OR: 12% Kitchen;* 8% Lab: 4% X-Ray *					Raw TOC 227
2000 N	1						
2000 N	5						
2000 N	10						
2000 N	25				12	199	
2000 N	50				15	118	
2000 N	100				13	118	
					Raw Turb 56		

Composites (Cont'd)

Carbon	Cat-Floc	Atlasep 105C	Atlasep 1A1	Atlasep 2A2	Turbidity (JTU)	TOC	
Time: 800 min from start up		V 41% OR; 23% Shower; 19% Kitchen (with Sparkleen); 12% Lab; 5% X-Ray					Raw TOC 284
2000 N	1	–	–	–	NC	NC	
2000 N	5	–	–	–	NC	NC	
2000 N	10	–	–	–	NC	NC	
2000 N	25	–	–	–	–	–	
2000 N	50	–	–	–	–	–	
2000 N	100	–	–	–	14	145	
					Raw Turb=44		

Note: Carbon: Hydrodarco C except as noted by "N" for Nuchar A.

– No Data.

NC: No coagulation.

* No Sparkleen